JRC Scientific and Technical Reports

Technical, operational and logistical parameters influencing emissions of heavy duty vehicles

Based on real-world emission measurements of HDV along the extended Trans-European transport CORRIDOR V

M. Pregl, A. Perujo, P. Bonnel

EUR 23659 EN - 2008

EUROPEAN COMMISSION

Institute for Environment and Sustainability

The mission of the Institute for Environment and Sustainability is to provide scientific-technical support to the European Union's Policies for the protection and sustainable development of the European and global environment.

European Commission
Joint Research Centre
Institute for Environment and Sustainability

Contact information
Address: European Commission – DG Joint Research Centre Institute for Environment and Sustainability
Transport and Air Quality Unit Via Enrico Fermi 1 – TP441 I – 21020 Ispra (VA) ITALY
E-mail: milos.pregl@jrc.it
Tel.: +39 0332 78 6782
Fax: +39 0332 78 5236

http://ies.jrc.ec.europa.eu/
http://www.jrc.ec.europa.eu/

JRC 48845

EUR 23659 EN
ISBN 978-92-79-11071-9
ISSN 1018-5593
DOI 10.2788/52697

Luxembourg: Office for Official Publications of the European Communities

Printed in Italy

Summary

Transport emissions of vehicles operating in real life are influenced by direct and indirect factors. Because of these factors, it is important to measure accurately the emissions from combustion engines under real-world conditions in order to provide realistic figures for an emission inventory.

The real-world emissions of heavy duty vehicles were measured in two preliminary measurement campaigns. Based on the collected data this report deals with heavy duty vehicle emission in different real-world transport conditions and their correlations i.e. transport factors influencing emissions.

These factors are mainly represented by technical, operational and logistical parameters. The technical parameters are vehicle characteristics such as engine type, loading capacity, weight of vehicle. Operational factors are connected with the way the vehicle is used on the road, such as speed and driving dynamic. This is strongly connected with the characteristic of the infrastructure and transport flow density. Logistical parameters are related with manoeuvring and other operations of the vehicle while cargo loading and unloading.

Emissions driven by the above mentioned factors must be considered in order to give proper inputs to transport policy decision makers. Consequently the primary scope of the work is to analyze the collected data in order to obtain a correlation between transport parameters and the emissions of heavy duty vehicle. Based on these assessments the secondary scope of the work is to identify both, the most important parameters influencing the emissions and also missing parameters within the measurement campaign in order to ensure more exact observations in the future.

As a next step the findings of this report can be compared to emissions factor of similar vehicles obtained by different emission models.

Acknowledgment:

We would like to thank Mr. Marjan Bezjak the owner and the director of the Fa Maik Company who provided HDV to perform the measurements. Also many thanks to his son Miha Bezjak the student of the Logistic University from Celje and to the driver for helping us at the logistic procedures during the more then 3000 km long journey to Barcelona and back.

In additional we would like to congratulate the team of VELA laboratories for performing such long measurement for first time in Europe

From left to the right: The author with Mr. Marjan Bezjak and his son Miha Bezjak

Table of Contents

List of Tables

List of Figures

1. INTRODUCTION

This report is part of the JRC's work program FP7 (WP2008, Sustrans action n° 13201) which is carried out in the Institute for the Environment and Sustainability.

Transport is a key factor in modern economic development, as economic growth requires readily access to resources and market. The need for mobility and economical growth has as side effects rising volumes of traffic and levels of congestions with significant impact on health and the environment.

The Action aims at designing strategies to achieve environmentally sustainable transport by defining the role of different transport modes in a framework based on sustainability, efficiency and competitiveness objectives. It also integrates the environmental analysis with socio-economic issues in order to define policy strategies for sustainable transport and to assess their environmental, social and economic impacts.

One of the objectives of the action is to define an integrated approach for a Trans-European Transport Network and to assess the environmental impacts and other implications of different transport modes (short sea shipping, rail and road transport and their combinations) along the extended trans-European transport Corridor V (Lisbon-Kiev).

Transport emissions of running vehicles in real life are influenced by direct and indirect factors. The real emissions of heavy duty vehicles were measured by the Vela laboratories in two preliminary measurement campaigns. Based on measured and collected data this report deals with heavy duty vehicle emission in different real-world transport conditions and their correlations i.e. transport factors influence on emissions.

1.1. Background

Globalization, the development of the Single Market and EU enlargement constantly increase the transport demand. The growth of the transport sector has significant environmental impacts and contributes to excessive depletion of natural resources. This growth has caused overloading of the transport infrastructure and adverse environmental impacts. In line with the UE transport Policy the priority should be given to rebalancing all the transport modes and supporting environmental friendly modes to become competitive alternatives.

The European market (and productions) depends on the long distance shipment of goods to be delivered on the most economical way, from door to door and on time. Using of heavy duty vehicles to satisfy these requirements is the common respond of the transport market. However the requirements of a sustainable development involve a shift to other transport modes such as rail and short sea shipping to reduce congestion and possibly also environmental impacts.

In order to support the development of an equilibrated transport infrastructures and to provide some inputs to the decision makers in finding a sustainable balance between different transport modes, a case study was proposed to assess the environmental impacts and other implications of different transport modes (short sea shipping, rail and road transport and their combinations) along the extended transport Corridor V (Lisbon – Kiev)[1]. Heavy duty transport is the main object in the proposed study because it represents a significant part of European traffic flows. The effects of this long distance

[1] JRC,-IES: Transport and Environment: an integrated analysis.(Case study: Pan-European Corridor V) – ver. 11 (TRAENVIA)

transport can be then compared either to the other modes or to other types of transport in specific mode (freight transport / passenger: long distance/urban…).

In the conventional tests (laboratory homologation or development tests), light road vehicles (light duty and two-wheelers) are tested under ideal conditions and predefined driving cycles. While the quality of the laboratory data is high, it is difficult to translate these results into the real world conditions where weather, altitude, vehicle loading, fuel quality and traffic effects will have a significant effect upon the emissions and the fuel consumption. Because of the factors mentioned above and in order to provide realistic figures for an emission inventory, it is important to measure accurately the emissions from combustion engines under real-world conditions.

In order to get the first impression about influence of traffic parameters on the value of emissions, based only on few short distance experiments with PEMS[2], it was decided to carry out a long distance real world emissions measurement campaign. Due to the importance and dimension of use of heavy duty vehicles in the road transport a typical and most common heavy freight vehicle was selected for the preliminary measurements. Due to significant increasing of freight transport in the past years in the direction east to west a special journey of the mentioned truck was organized. The team collected 50 hour of data on the route between Maribor (Slovenia) to Barcelona (Spain).

1.2. Objectives

Emissions of vehicles are influenced by different factors that are mainly represented by technical, operational and logistical parameters. The technical parameters are vehicle characteristics such as engine type, loading capacity, weight of vehicle. Operational factors are connected with the way the vehicle is used on the road, such as speed and driving dynamic. This is strongly connected with the characteristic of the infrastructure and transport flow density. Logistical parameters are related with for example, the occupancy rate for passenger or load factors for freight transport respectively.

The emission models are able to account for some of these parameters, but it is not clear how they perform in some extreme situations, like congestion, border crossing, road toll stations, etc. The influence of these parameters on the emissions needs to be quantified in order to provide inputs for optimization of the transport system and to minimize the emissions and consequently environmental impacts.

Emissions driven by the above mentioned factors must be considered in order to give proper inputs to transport policy decision makers. Consequently the scope of the work is to analyze the collected data in order to obtain a correlation between transport parameters and the emissions of heavy duty vehicle. This can be elaborate trough the careful observation of the factors dynamic which are collected during the campaign.

Based on the considerations above the objectives of this report are the following:

- To describe the method of real world emissions measurements on board of heavy duty vehicle and the data collection
- To analyze the influence on emission of the technical parameters of the vehicle such as:
  - engine type
  - loading capacity
  - weight of vehicle

[2] Portable Emission Measurement System

- To analyze the influence on the emission of the operational parameters of the vehicle such as
    - speed
    - driving dynamic
        - different types of vehicle operation (different drivers)
        - optimal – non optimal type of operation
        - characteristic of the infrastructure
        - optimal (flat) type of road
        - road slope
        - urban – non urban roads
        - highway cycle
        - weather conditions
    - transport flows density
        - congestions
        - free flow traffic
    - extreme situations (administrative constrains)
        - toll stations
        - border crossing
        - weight control stations
- To analyze the influence on the emission on logistical factors such as**:**
    - occupancy rate
    - emissions at loading and uploading
    - idle running of the engine (driver resting periods – heating, etc)

2. REAL WORLD EMISSION MEASUREMENTS

The idea of measuring the emissions in real conditions on board of an operating vehicle is not new. Several methods and devices have been proposed and used in the past, And a continuous feedback from scientist requiring a higher precision on the measured parameters have improved the devices in a very short period of time. In the preliminary measurement campaign between Maribor (Slovenia) and Barcelona (Spain) one of the most advanced equipment was used and changes were implemented in order to perform a long distance measuring campaign.

2.1. The area of the campaign

During recent years a significant increase of traffic has been noticed on European roads. This increase is more notable in the direction east to west after the accession to the EU of the east European countries.

The most representative and also politically recognized traffic increasing direction is in the direction of so-called Corridor V. The impact of the long distance heavy goods transport is here quite significant. The Corridor is crossing also important European urban areas where the emission caused by traffic due to congestions is potentially very high.

The Corridor V is more than 3000 km long. In transport terms we can talk about 3000 different situations and conditions which can heavily influence the traffic flow and consequently the emissions. The measurement of emissions in real traffic conditions was a specific challenge and an unique experience.

In the process of pre-measuring campaigns and partnership activities several countries and partners joint the project TRAENVIA. One of the Slovenian logistic company from Maribor[3] put one of their heavy duty vehicle at the project's disposal to perform a preliminary campaign, and with their support two special journeys were organized:

- Maribor - Ljubljana (October 2006)
- Maribor - Barcelona return to Milano (February 2007)

2.1.1. Measurement campaign Maribor - Ljubljana

The first measurement campaign was performed between Maribor and Ljubljana (fig. 1) in flowing traffic conditions.. The average speed was 82,5 km/h. This velocity is lower than the optimum (90 km/h) because of driving in urban areas at the beginning in Maribor and stops at toll stations. The trip was 120 km long and the crew collected 1,5 hours of data.

Figure 1 First measuring campaign between Maribor and Ljubljana

In transport infrastructure terms, the trip was performed manly on motorways and in roads with optimal slopes, which according to road construction regulations can not be higher then 3%. The weather conditions were also optimal for this time of the year, and the vehicle was not fully loaded.

2.1.2. Measurement campaign Maribor - Barcelona

The second campaign was much more demanding (fig. 2) as compared with the previous one. It was divided in 15 segments. The journey together with the preparation and installation of the equipment took more than two weeks. The preparation started in Ispra at the JRC and after taking a load nearby to Lecco the journey proceeded toward Maribor where the goods were delivered. A new load was then taken to Barcelona and after logistical procedures (unload of the cargo and load of new cargo) the vehicle turned back to Ispra.

[3] Fa – maik logistika, Maribor, Slovenia (http://www.fa-maik.com/)

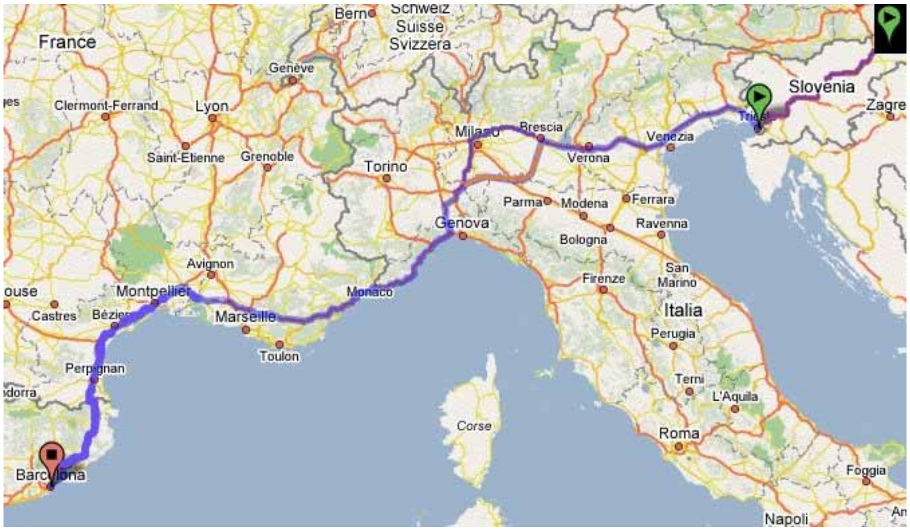

Figure 2 Measuring campaign between Maribor and Barcelona

In this occasion the traffic conditions were very varied fluctuating from free-flow to "bottlenecks" situations. All types of driving conditions were present (from urban to suburban conditions). Also the infrastructure differed from place to place. Because of the non fluent traffic conditions the average speed was lower than the speed in the first campaign. The daily averages oscillated from 45- 85 km/h depending on the traffic conditions and cycle of driving.

Because the cargo was not all the time the same also the gross weight of the vehicle had different influence within different sections of the journey. This can be analyzed to extract the influence of the gross weight of the vehicle on emissions.

The crew collected more than 50 hours of data for a journey of 3539 km.

2.2. The measurement equipment and the test vehicle

The intent of the campaign was to collect emissions and operation data from a diesel truck which was operating for the trans-border transportation of goods and to provide a large emissions data set usable for source modeling. This data can be the base for establishing the relationship between the emissions and the activity parameters for a wide range of operating conditions.

2.2.1. The equipment – Portable emission measurement system

The European Commission through its DG ENTR in co-operation with DG JRC launched in January 2004 a co-operative research program to study the feasibility of Portable Emission Measurement Systems (PEMS) with a view to their application in Europe for in-use conformity (IUC) checking of heavy-duty vehicles[4]. The main instrumentation requirements defined in the preparatory stages of the project were the following:

- To be small, lightweight and easy to install;
- To work with a low power consumption so that tests of at least three hours can be run either with a small generator or a set of batteries;
- To measure and record the concentrations of NOx, CO, CO2, THC gases in the exhaust;

[4] European project on portable emissions measurement systems: "EU-PEMS" project - Status and activity report 2004-2005

- To record the relevant parameters (engine data from the ECU, vehicle position from the GPS, weather data) on an included data logger;
- To be robust and have the possibility to work under demanding environmental conditions, such as – amongst others – temperature and vibrations

Testing using Portable Emissions Measurement Systems (PEMS) offer a modern and innovative counterpart to check the impact of emissions from combustion engines upon the environment. It can provide real time and real-world emissions monitoring of combustion engines (***on mobile sources***) under their real in-service operation.

The PEMS used to perform the present tests is a Semtech-DS from Sensors Inc.

The main parts of the system are (fig.3):
- The gas analyzers (to measure CO2 and the regulated gaseous pollutants THC, CO, NOx)
- Exhaust flow meter
- Connection to vehicle ECU
- GPS
- Weather station
- Computer for test management and data logging

Figure 3 Installation of the PEMS (the main unit for emissions analysis, connections, flow meter at truck tailpipe)

2.2.2. The test vehicle

The traffic share of heavy duty vehicles oscillates along the Corridor V. and it represents in average traffic conditions 12 -18 % of the total vehicle fleet.[5] It is obvious that this share is much bigger around logistic centers and urban areas. The typical heavy duty vehicle for long distance transport is a 40 t truck with semi trailer. The average age of the heavy duty vehicles fleet differs from country to country (from 5-10 years). Due to technical and competition reasons the vehicles used for long distance international transportation are usually newer than vehicles used for national short distance transportation.

Taking into account the mentioned vehicle fleet characteristics, the representative heavy duty vehicle running along the corridor V. is approximately 5-6 year old with EUROIII diesel engine without

[5] The traffic counting data reports; Slovenian national road administration

particle trap. This vehicle normally followed the maintenance schedule recommended by the manufacturer.

From the vehicle fleet of Slovenian Fa Maik logistic company one adequate vehicle was selected (fig. 4).

Figure 4 MAN heavy duty vehicle with semi trailer

The selected truck corresponded to the characteristics of the most common and representative heavy duty vehicles along the Corridor V (table 1). It was a MAN truck produced in the year 2000 with EURO III engine.

Table 5 Technical specification of the test vehicle

Vehicle Owner:	Fa Maik logistic - Maribor - Slovenia	
Vehicle type:	Truck	
Vehicle Manufacturer:	MAN	
Vehicle Identification Number:	WMAH12ZZ24M390355	
Vehicle model year:	2000	
vehicle weight [kg]	14790	
Engine manufacturer:	MAN	
Engine model/year:	D2866LF28 / n.a.	
Engine ID#:	5350679022B2E1	
Engine displacement [lit]:	11.967	
Number of cylinders:	6	
Engine rated power: [kW @ rpm]	301 @ 1900	ISO 1585
Engine peak torque: [N.m @ rpm]	1850 @ 1000-1300	ISO 1585
Idle speed [rpm]:	600	
ECU Protocol:	J1939	
Fuel type:	DIESEL	
Particulate trap	No	
Catalytic converter	No	

2.3. Measurement procedure

The measurements are performed by the different components of the PEMS[6]. The main test parameters can be divided in three categories:

- Ambient (temperature, humidity, wind) and road (grade) conditions;
- Vehicle parameters (vehicle speed and engine parameters, engine load);
- Vehicle output (emissions, exhaust mass flow).

Because of the length of the journey, the campaign was divided in several cycles whose duration was approximately 2 hours. After each cycle, a calibration and verification of the measurement device (PEMS) were performed, which involved a 15 – 20 min. interruption in the normal vehicle journey. Additionally the legislations regarding driver rests and maximum time and length of driving were fulfilled.

All procedures required a team of technicians with special equipment and tools. Apart of the vehicle driver and the representative of the company, the testing team consisted of 3-4 members. One of them was in the truck's cabin and the others were following the test vehicle in the van with the equipment (fig. 5).

Figure 5 The test vehicle with the accompanied support van

During the test cycle, all the mentioned parameters (from vehicle system and from installed sensors) were recorded each second and stored in to the computer on board (fig. 6).

[6] JRC, IES: European project on portable emissions measurement systems: "EU-PEMS" project; Technical report road tests on heavy-duty vehicles

Figure 6 Installation of main PEMS unit (Gas analyzer) and computer

After each measurement cycle (the longest campaign from Maribor to Barcelona and back consisted of 19 cycles) the data were stored in the computer for later further analysis. The list of the test parameters is following (table 2):

Table 6 List of parameters stored into the computer during the measurement cycle

	Parameter	Unit
TIME DISTANCE	Time	s
	Cumul_Distance	km
DRY CONCENTRATIONS OF GASES	CO2	ppm
	CO	ppm
	NO	ppm
	NO2	ppm
	NOx	ppm
	THC	ppmC
AMBIENT CONDITIONS	Relative Humidity	%
	Absolute Humidity	g/kg dry air
	Ambient Pressure	kPa
	Ambient Temperature	deg C
EXHAUST FLOW PARAMETERS	Corrected Exhaust Mass Flow	kg/h
	Exhaust Volume Flow	m3/s
	Exhaust Temperature	deg C
VEHICLE AND ENGINE PARAMETERS	Vehicle Speed	km/h
	Engine Torque	N.m
	Engine Speed	rpm
	Boost Pressure	kPa
	Fuel Rate	g/s
	Intake Manifold Temperature	deg C
	Engine Coolant Temperature	deg C
	Actual Throttle Position	%
	Actual EngineP Torque OR P Load	%
	FrictionTorque	%
GPS DATA	Latitude	deg
	Longitude	deg
	GPS Vehicle Speed	km/h
	Altitude	m3/s

After the whole measurement campaign was completed, the data were adjusted in a more convenient format in order to have a more appropriate and easier-to-handle data for further analysis. This data can be divided in the following groups:

- Time and distance parameters
- Mass emissions (CO2, CO, NOx in g/s)
- Cumulative mass emissions (CO2, CO, NOx in g)
- Distance cumulative mass emissions
- Fuel rate, fuel consumption and emissions per kg fuel (CO2, CO, NOx in g/kg)

With the described data, exacts emissions can be identified in space, time and under parameters which are influencing on vehicle emissions (load, velocity…). With the positioning data, the characteristics of infrastructure can be estimated. In other words with the examination of the collected data the influence on the emission on the operational parameters of the vehicle can be derived.

3. OVERALL EMISSIONS

For both measurements campaigns:

- Maribor - Ljubljana (in the following text: pretest) and
- Milano – Maribor – Barcelona – Milano (in the following text: test)

The total emissions can be estimated from the collected data as following (table 3):

Table 7 Total emissions for both campaigns (pre-test and test)

	CO2 g in total	NOx g in total	CO2 g/km	NOx g/km
Pretest	67046,00	478,23	551,96	4,01
Test	3527345,25	32335,98	669,96	6,14

It is reasonable to find a difference between the values of the pre-test as compared with those of the test because of a lightest cargo in the pre-test. The correlations between the emissions and the cargo weight will be presented in the following chapters. They are mentioned at this point of the report to support the discrepancy between the emissions produced from the truck which was in one direction fully loaded and in the other direction half loaded. The 40 t truck produced within the 3539 km long trip 3,5 t of CO2. In other word the truck produced approximately 1 t of CO2 per 1000 km. Per transported tone of goods carrying along the mentioned distance, the truck produced approximately 180 kg of CO2. These facts are impressive if you look on them in total. But due to transport parameters influence on the level of the emission and taking into account distance and time dimension, the picture is different. This can be clearly seen on the following chapters.

3.1. Pretest Maribor - Ljubljana

In the following figures (fig 7 and 8) depicting CO_2 and NOx emissions correlated with the vehicle position it can be noticed that the emissions are higher around urban areas (on the beginning in and around Maribor). This is due to two up-hill road sections in the direction to Ljubljana. Two other similar situations can be also seen. The reason for the brake at the end was a technical breakdown of PEMS data acquisition.

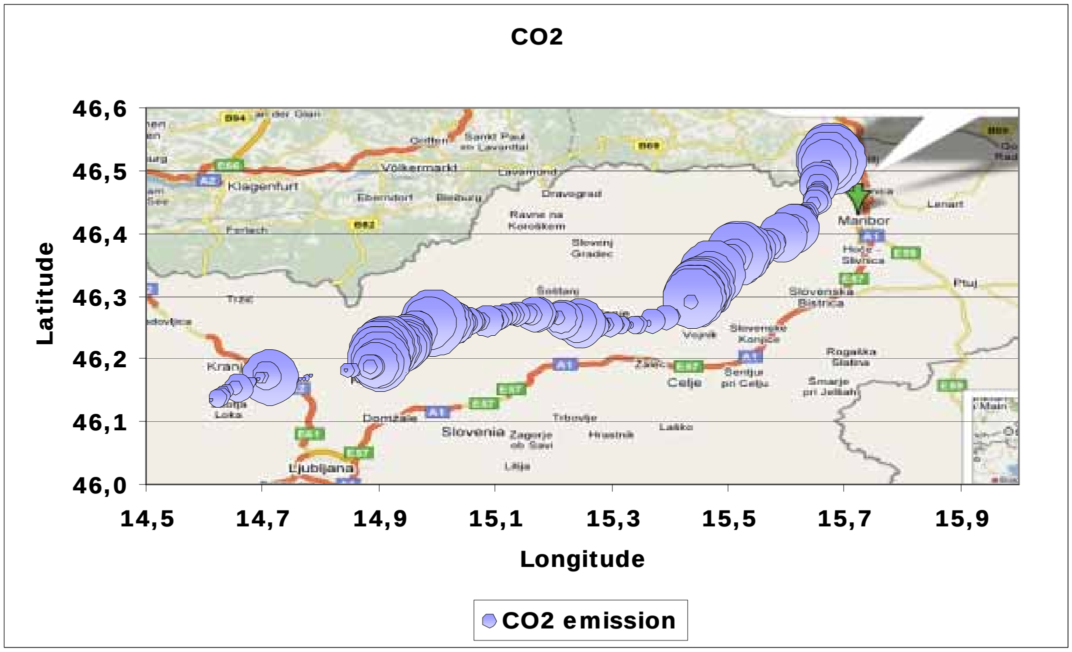

Figure 7 CO2 emissions during the pretest between Maribor and Ljubljana

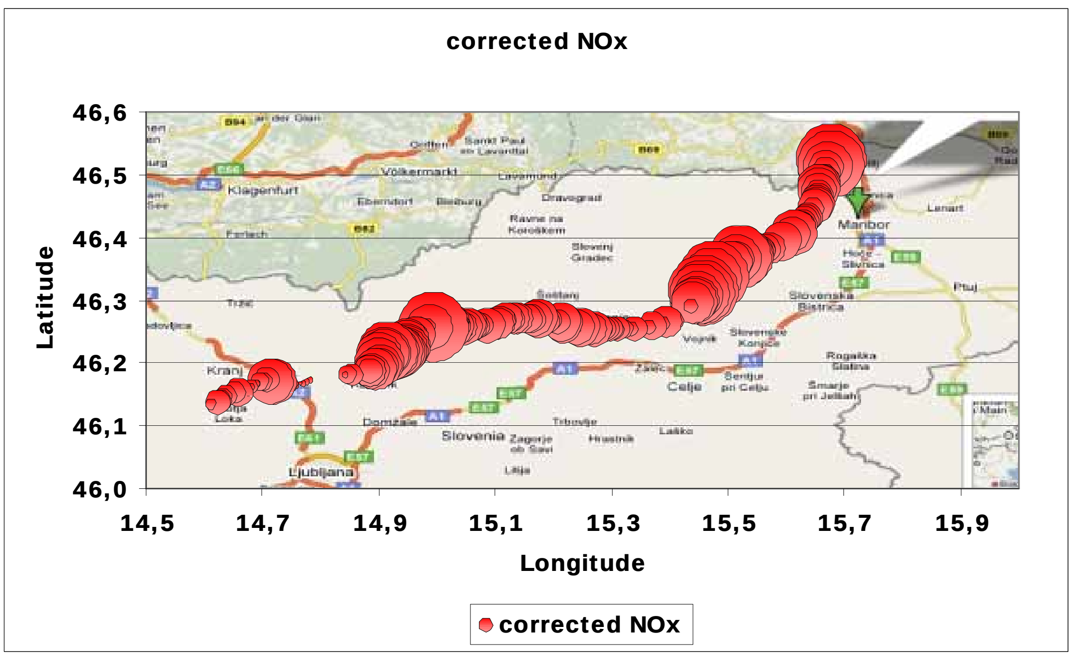

Figure 8 NOx emissions during the pre-test between Maribor and Ljubljana

3.2. Test: Milano – Maribor – Barcelona – Milano

Based on above mentioned experience the real test was performed after solving the technical problems encountered. The completed overall results of CO2 measurements between Ispra and Trieste are given in fig. 9

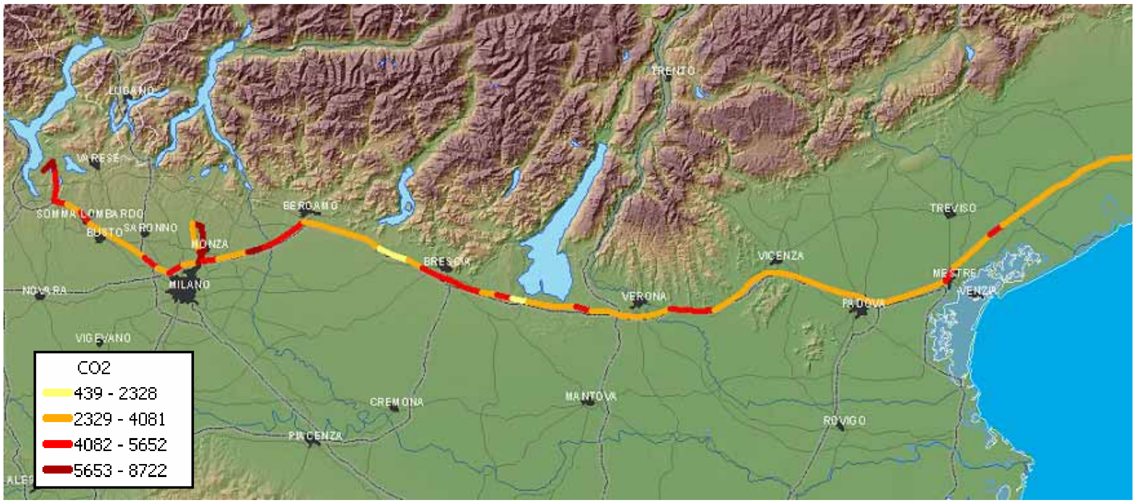

Figure 9 CO2 emissions during the test between Ispra and Maribor (in g per 5 km sections)

The emissions are significant higher around urban areas and on the sections where the traffic is usually congested. A similar pattern can be seen for NOx emissions (fig. 10)

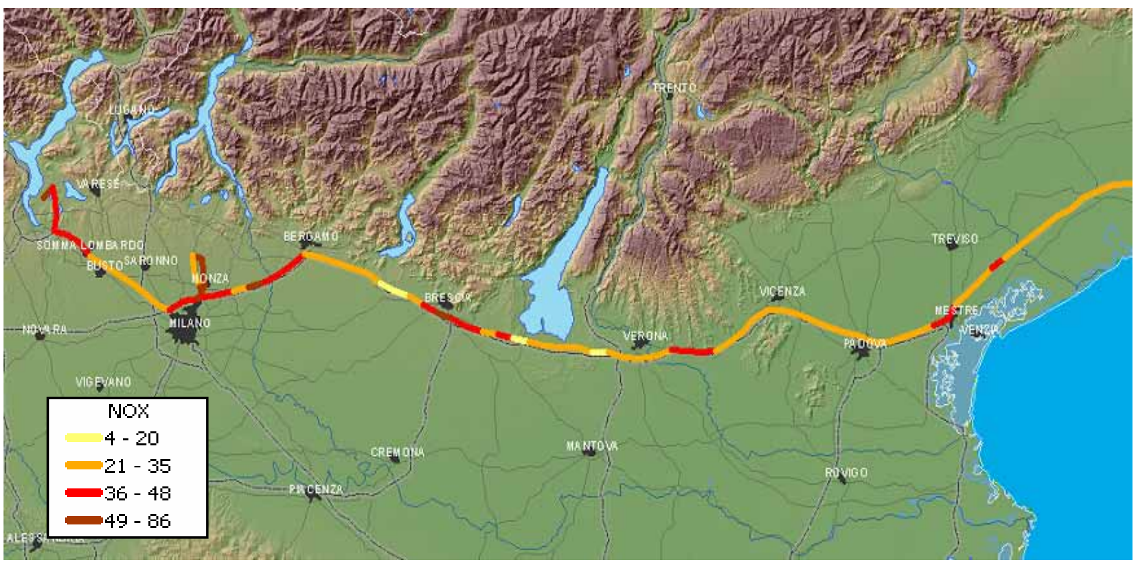

Figure 10 NOx emissions during the test between Ispra and Maribor (in g per 5 km sections)

In Figures 9 and 10 it can be noticed that emissions changed along the path of vehicle (changes from red to yellow portions). The red portions indicate higher emissions due to, among others, traffic congestions around bigger urban areas (Milano, Venezia) or characteristics of the infrastructure. If we turn now our attention to the whole study area, then similar observations can be noticed (figs.11 and 12). The emission levels are this time higher on the coastal area of France, possibly due to higher road slopes is some portions.

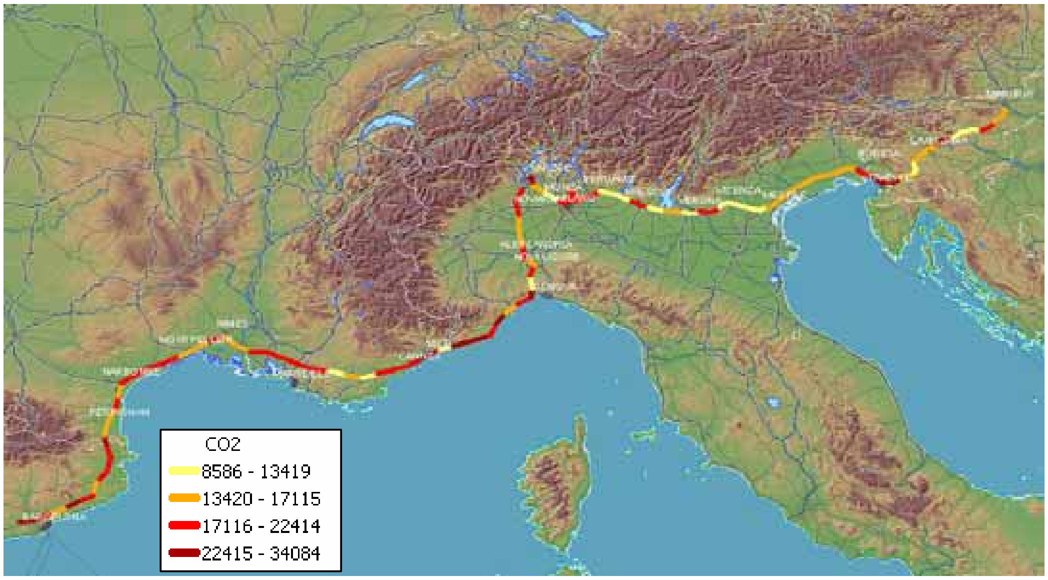

Figure 11 CO2 emissions between Barcelona and Maribor (g per 20 km sections)

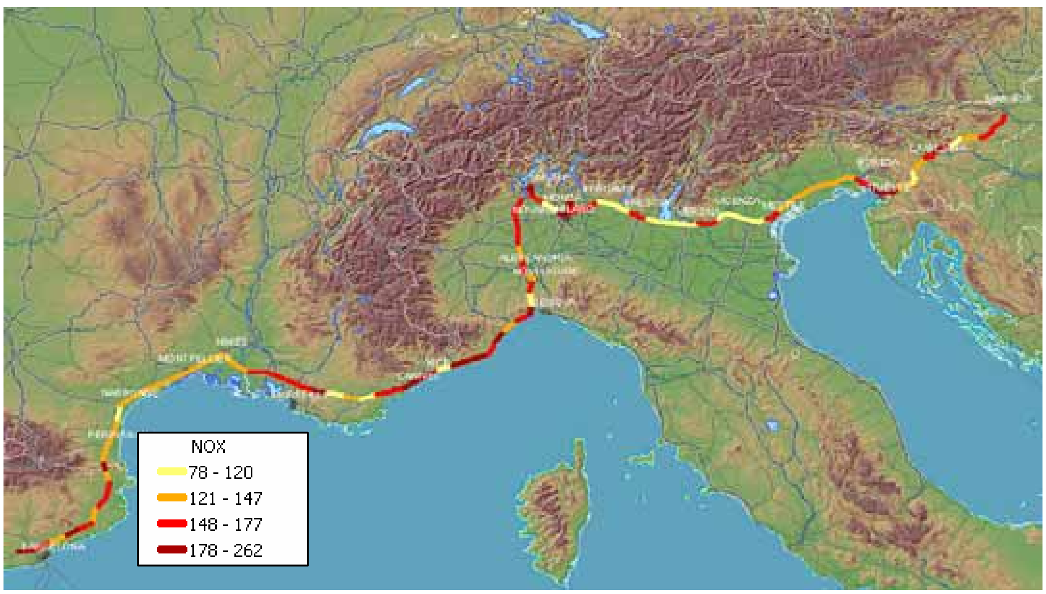

Figure 12 NOx emissions between Barcelona and Maribor (g per 20 km sections)

The above paragraphs give an overview of the variations of emissions along the vehicle's route. To establish correlations with technical, operational and logistical parameters dedicated further analysis of the collected data is needed. This is the aim of the following chapters.

4. VEHICLE PARAMETERS AND EMISSIONS

The most common technical parameters of the vehicle influencing on emissions are:

- engine type
- loading capacity
- weight of vehicle

The basis for the collected data was only one vehicle (with one engine type), consequently it is not possible to analyze of correlations between engine type and emissions. But due to the fact that the vehicle past a certain sections of road at least tree times with different load the weight related factors can be evaluated. Within the pretest and test campaign the vehicle had six different weight conditions and if we find similar road section all of these conditions can be evaluated.

4.1. Influence of the gross weight of the vehicle

The vehicle was running three times on the same road section with different load between Maribor and Ljubljana. The gross vehicle weight ratings at the mentioned rides were:

- 18000 kg within the pretest in October 2006
- 30750 kg and 39190 within the test in February 2007

The sections were chosen according to the following operation parameters:

- The road section should be as flat as possible. In the specific case the average altitude of the selected section was 277 ± 2 m.
- As far as possible the vehicle should run along this section with approximately constant speed (aprox. 90 km/h)
- The vehicle torque and other engine parameters should be at the same level

After the examination of the data one km Slovenian motorway section between junction Rače-Fram and junction Zgornja Polskava, was selected.

The CO2 and NOx emissions are presented in the following figures 13 and 14.

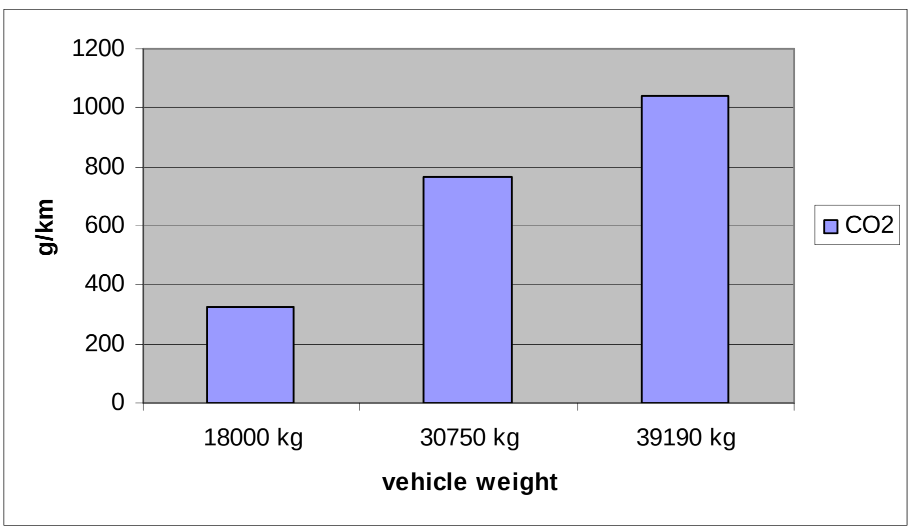

Figure 13 CO2 distance-specific emissions at different gross weight of the truck

It is obviously that CO_2 emissions increase nearly proportional to the vehicle weight, but that is not the case for NOx emissions:

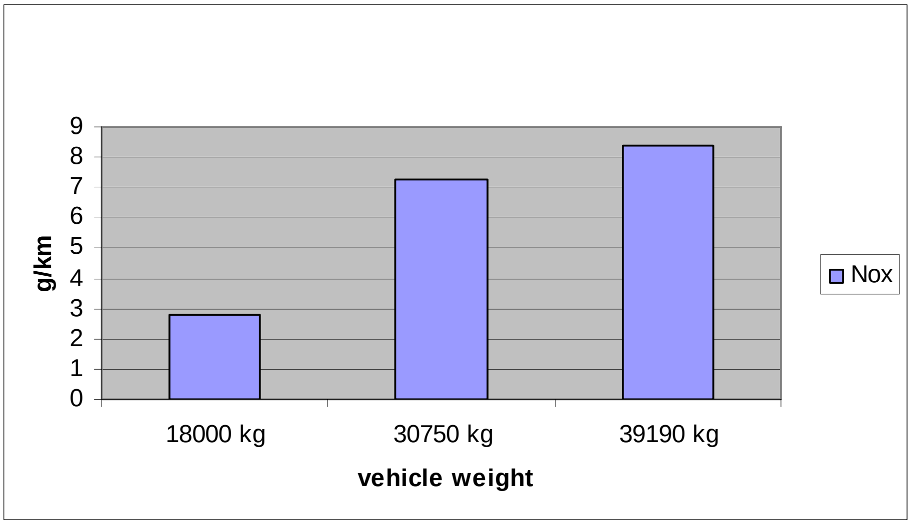

Figure 14 NOx distance-specific emissions at different gross weight of the truck

After the significant increasing between the first and the second considered weight of the vehicle (5, 21 g/km), a smaller increase (for 1,1 g/km) of NOx can be seen at highest weight.

It is very difficult to predict the correlation between emissions and gross vehicle weight based only on three examples. Additional comparison of similar situations on road sections (ideal speed, flat road section…) is needed. From the collected data is possible to derive two additional and similar situations where the load was different:

- 22790 kg on the section from Ispra to Monza
- 27080 kg on the section from Barcelona to Milano

For the first situation a road section was selected on the A8 Motorway near Gallarate (IT), where the change in altitude was at the minimum (2m). The speed of the vehicle was also at the optimum value (89-92 km/h).

For the second situation a motorway section on the A9 near junction to Le Boulouwas (F) was selected. Also here the change in altitude and speed was approximately the same.

The results show a significant and nearly linear increase of CO_2 each time the vehicle weight increases (fig. 15).

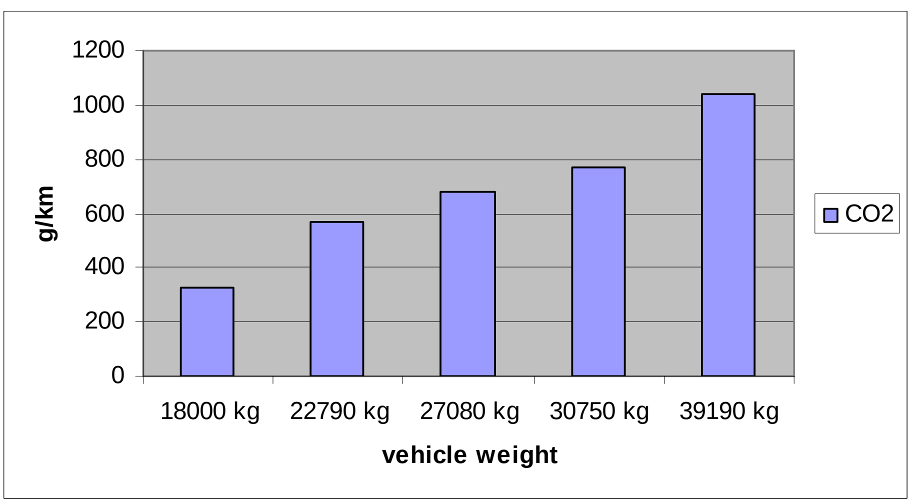

Figure 15 CO_2 emissions at different gross weight of the truck

A similar trend can be seen for NOx emissions (fig. 16):

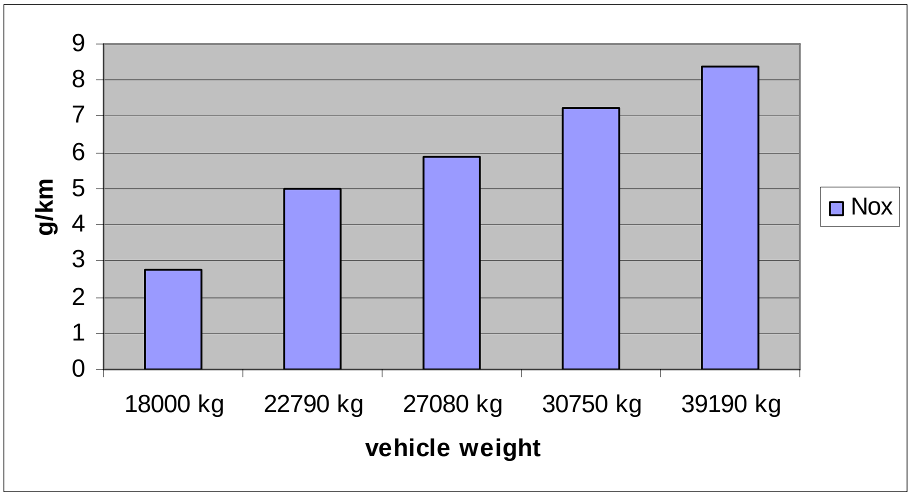

Figure 16 NOx emissions at different gross weight of the truck

From the above data is clear that the gross vehicle weight has a significant influence on the emissions. From the transport policy point of view is more important how much of emissions are produced per one ton of goods transported over one kilometer. This is the aim of the next subchapter.

4.2. Influence of load occupancy

During the test (and pretest) the truck was loaded with different loads. Consequently the truck was running along the Corridor V under different load occupancy rate (from 13% within the pretest to 97% within the journey from Maribor to Barcelona) (table 4):

Table 8 Load occupancy for different journey sections

Relation	km	Load occupancy
Maribor - Ljubljana	121	12,73%
Ispra - Monza	89	31,73%
Monza - Maribor	629	63,71%
Maribor - Barcelona	1783	96,76%
Barcelona - Ispra	1038	48,75%

During the majority of the journey the vehicle was nearly fully loaded. The comparison between emissions and ton-kilometers clearly shows that emissions are much lower in the case of the higher occupancy of the vehicle (figs 17 and 18).

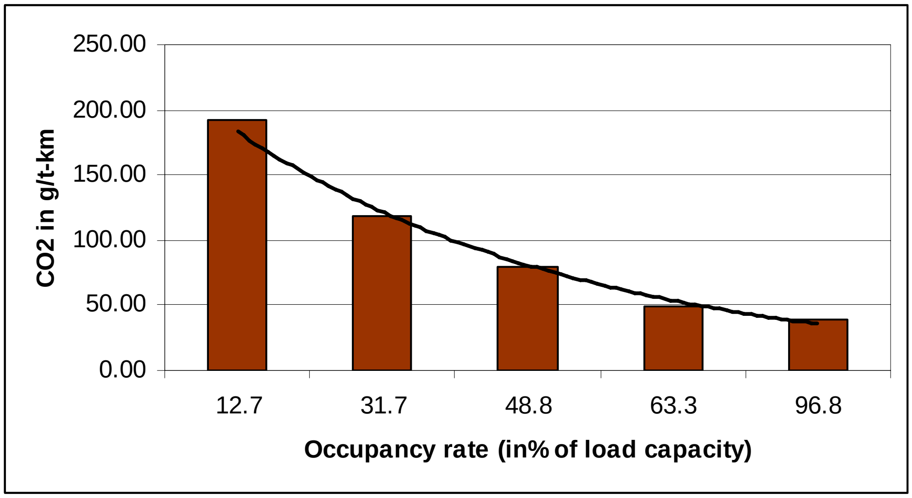

Figure 17 CO2 emissions per ton – kilometer at different load occupancy

At the minimal vehicle occupancy the CO2 emission is almost four times higher as compared to the maximum occupancy. When the occupancy is growing linearly the emissions are decreasing exponentially.

Similar relationship can be found in the case of NOx emissions. The only difference is that they are decreasing at a slower rate when the occupancy is growing. At the minimal vehicle occupancy the NOx emissions are four times higher as compared to at the maximum occupancy.

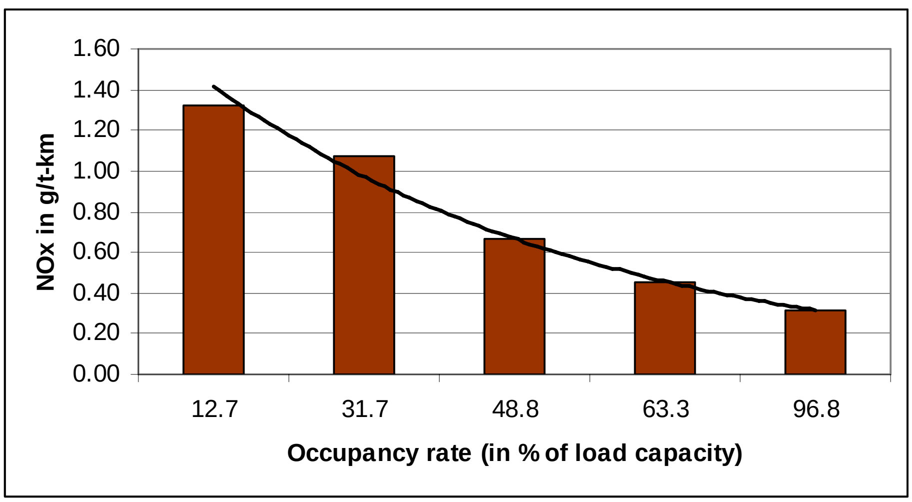

Figure 18 NOx emissions per ton – kilometer at different load occupancy

These figures are just opposite to the case where the comparison is made between the vehicle weight and the corresponding emissions. From an economical point of view is important that the vehicle capacity is utilized as much as possible. From the transport policy point of view is similar – as lower emissions are possible per unit of good transported over a certain distance.

In a every-day-life situation the utilization of the load capacity of vehicles is far away from the 100%. Due to the different types of cargo, heavy duty vehicles in practice are not fully loaded (a significant part of heavy duty vehicles are loaded with so called “volume cargo” like textiles). Consequently in road transport is usually assumed that the heavy goods vehicles are in general half loaded. This is also the critical point in our comparison when the emissions are starting to heavily fall in comparison to the load occupancy

In this chapter we have point out that the emissions in term of g per vehicle kilometer (g/km) increases with the occupancy of the vehicle (load occupancy) particularly for CO2 (see fig, 15). In the case of NOx the emissions remain constant from the 50% load occupancy (see fig. 16) However if we express the emissions in term of occupancy rate (g/t/km) there is an obvious correlation between an increase occupancy and reduction of emissions assigned to the transported goods.

5. OPERATIONAL PARAMETERS INFLUENCING EMISSIONS

Due to the traffic conditions in real world the operation of the vehicle differs from one situation to the next. This consequently has an impact on the speed of the vehicle as well as on their emissions. During a journey, human factor has a crucial influence in the manner a vehicle is operated (aggressive, balanced…). The driver with more experience can operate the vehicle in a more efficient and optimal way. The condition of the vehicle (and engine) is also important. Well maintained vehicles emit less than poorly maintain ones.

The second group of complex operational parameters is linked to the characteristic of the infrastructure. They may be optimal in terms of slope (flat road sections) and no optimal (uphill and downhill sections). Similar (but not in the same extent) influence has also the type of infrastructure (motorway, local, urban roads…). It is also very important in what kind of state the infrastructure is (maintaining of the roads, snow…).

The third sets of parameters are depending on the way the traffic is operated (traffic flow management). If the traffic is too dense and if it is not managed in a proper way the logical consequences are congestions, stop and go operation of the vehicle, etc.

In practice the traffic presents also “bureaucratic” situations like toll stations and border crossing controls. In some border crossing stations along the corridor V, even nowadays vehicles should wait several hours to clear the procedures. This can be considered as the fourth constraint of this group of operational parameters.

.

5.1. Speed of the vehicle and emissions

The speed of the vehicle depends on parameters like traffic density, driver behavior, road type etc. It is difficult to evaluate the effect of vehicle speed on emissions when studying the second by second data.

The multitude of different situations mentioned above dictates a need to average the data within different classes. In the present situation the emission data for each second were classified according to the speed situations from 40 km/h up to above 90 km/h. The second step was selection of speed classes and calculation of average within them. An appropriate value can be the median value of emissions within different speed classes, because it shows the middle number of a group of numbers (half of the numbers have values that are greater than the median, and half the numbers have values that are less than the median). After the described calculation the picture and the relative trend is much clearer. This illustrated in figures 19 and 20.

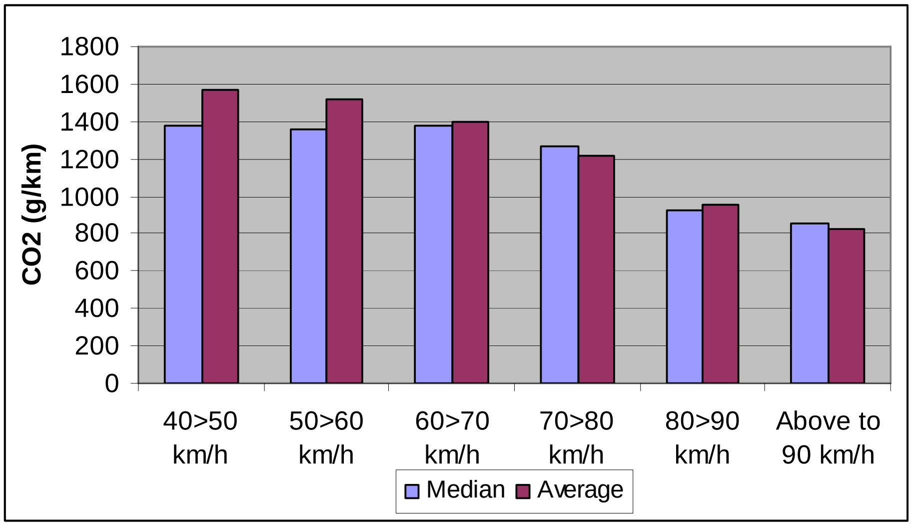

Figure 19 The median and average values of CO2 within the different speed classes

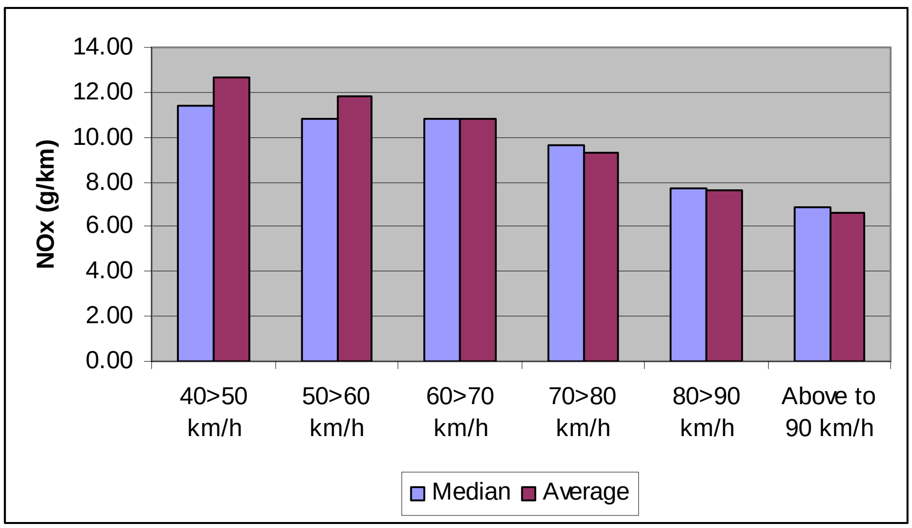

Figure 20 The median and average values of NOx **within the different speed classes**

The values of median and average are much closer in the three last bars because at these speeds the operation of the vehicle was more fluent. The speed range between 70 and 90 km/h is a normal speed in normal motorway traffic conditions.

The previous approach was evaluated for the 97% of the maximum load occupancy. As mentioned earlier in the document in the transport economy evaluation praxis is a common assumption that the heavy duty vehicles are running under 50% of their occupancy. Such situation occurred during the measurement campaign on the way back from Barcelona, when the vehicle vas loaded up to 49% of the maximum load occupancy. The evaluation of the effect of speed emissions under 49% load occupancy was performed in the same way as in the case of 97% load occupancy. The comparison of the emissions expressed in g/t/km within different speed classes between two load occupancy situations is the following (figs 21 and 22):

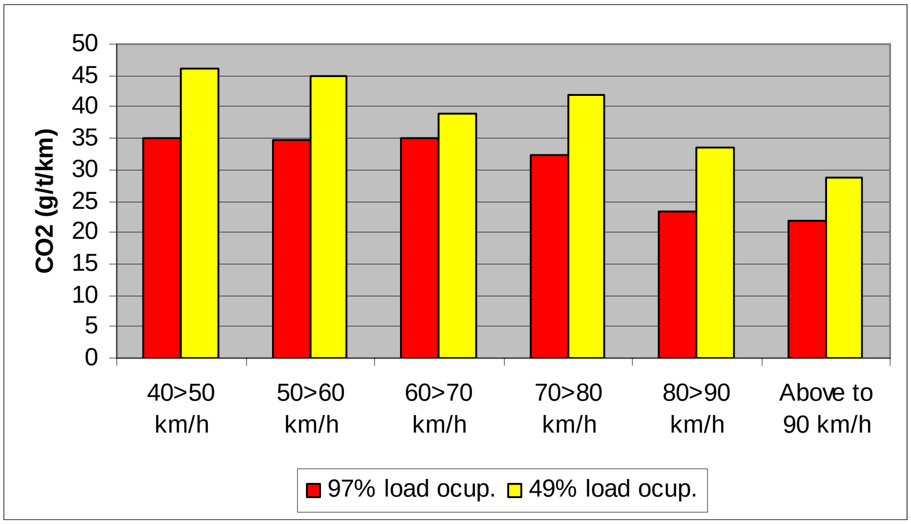

Figure 21 Median values of CO2(in g/t/km) within the different classes of speed for 97 and 48 % of maximum load occupancy

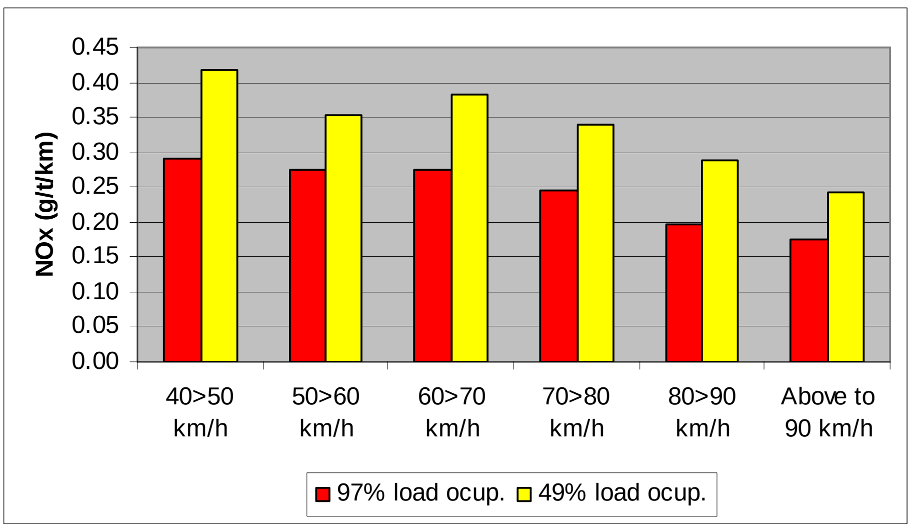

Figure 22 Median values of NOx (in g/t/km) within the different classes of speed between 97 and 48 % of maximum load occupancy

The discrepancy between different load occupancies is quite high.. In g/t/km term a fully loaded truck has up to 40 % less emission than half loaded. The load occupancy has a more significant influence at lower and higher speed classes.

The conclusion of the comparison is that the operation of a vehicle at maximum occupancy contributes with lower emissions in terms of g/t/km.

5.2. Dynamic of the vehicle operation and emissions

The dynamic of the operation of the vehicle was mentioned already several times. The dynamic of the operation depends apart from traffic situations mainly from the human factor. The dynamic can be stable when the vehicle is operated by expert drivers in the optimal conditions or it can be unstable when the vehicle is accelerating or decelerating or operated by less expert driver. The acceleration and deceleration is mainly a meter of the traffic conditions. This will be described in the following chapters. In this chapter the influence of the dynamic of the vehicle is evaluated only in the following manners:

- What kind of emissions can be expected from operating of the vehicle by a less-experienced driver,
- What are the quantities of emissions at accelerations of the vehicle compare to optimal operation of the vehicle.

The presumption of the comparisons in this chapter is that the road sections are flat and without effect of traffic

5.2.1. *Influence of the driver*

The test vehicle was also partly operated by a non-expert younger driver on its way back from Barcelona. He operated the vehicle within two measurements steps on this journey section. The truck was loaded to 48% of its load capacity. All other operations of the vehicle during the measurement campaign were performed by an expert driver with more than 8 years of experiences compared to the younger one who just passed his exam. Compare to the expert driver the younger driver operated the vehicle in a quite non fluent way and with less feeling for the capability of the engine. In other words the vehicle operated in no optimal way.

After the detailed examination of the measured data the following observations of different driver's behaviors can be derived. Figure 23 showed the evident appreciable difference between the engine speed operation in the case of expert driver operation of the vehicle (driver behavior 1) and in the case of non-expert driver operation of the vehicle (driver behavior 2).

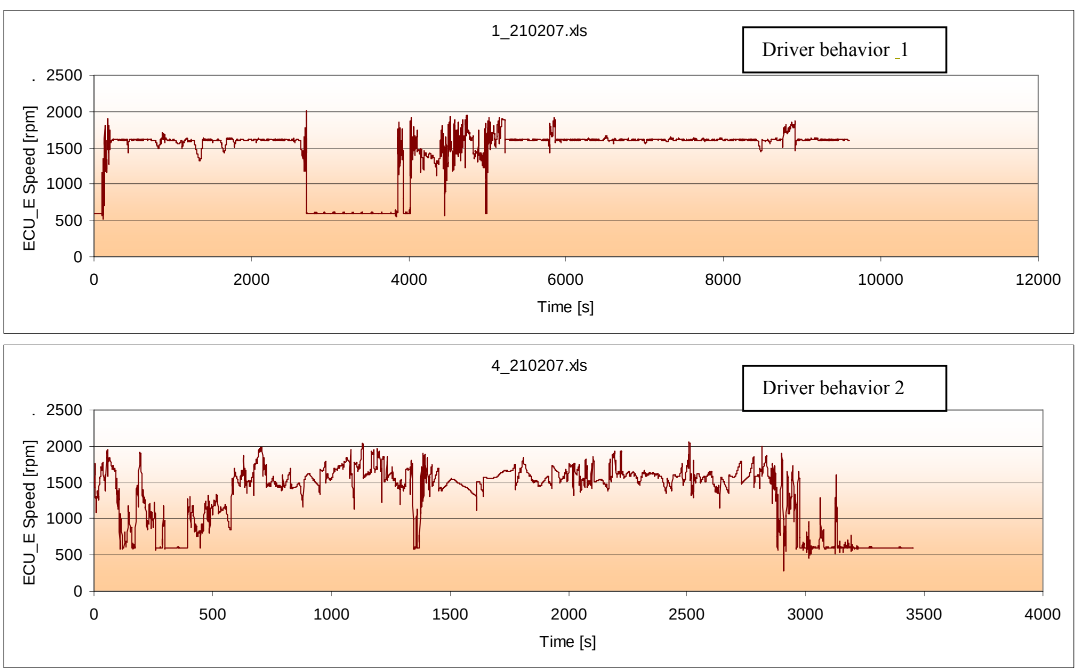

Figure 23 Engine speeds of the vehicle at different driver behaviors

The data in the mentioned Figures are very dense. Also the time dimension has its influence because of the traffic conditions which oscillated within this dimension. In the next step two short sections with similar traffic conditions for each driver behaviour were selected. The time frame was 3 min. The precondition was that the vehicle was operated close to the optimal speed, in free traffic flow and on a flat road section:

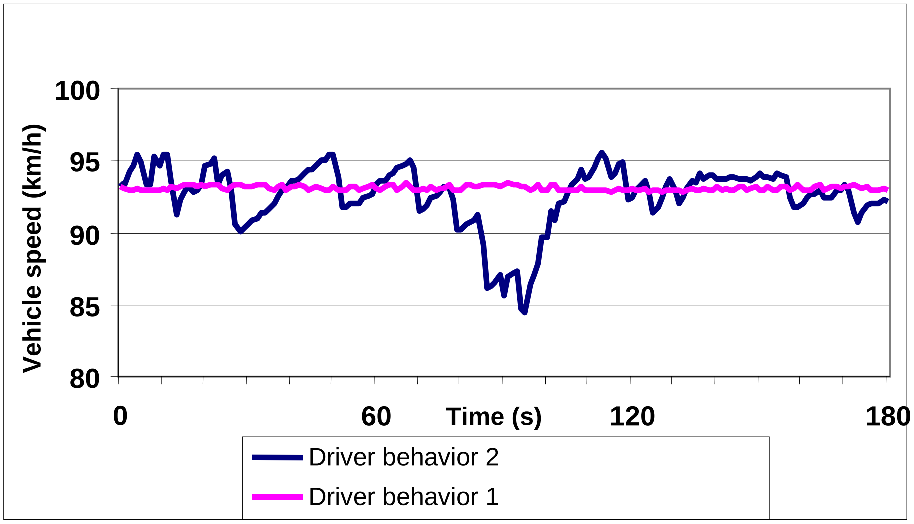

Figure 24 Vehicle speeds of the vehicle at different driver behaviors for a 3 min section

The difference is obvious also in the case of engine speed (fig. 25):

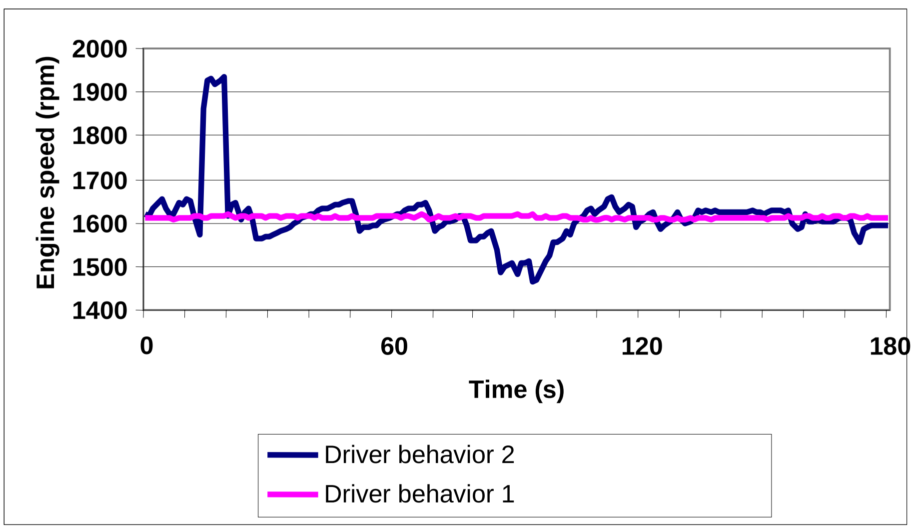

Figure 25 Engine speed of the vehicle at different driver behaviors for 3 min section

Both figures show that the vehicle and engine speeds for the driver behavior1 are almost straight; i.e. without acceleration or deceleration. After an additional survey of the involved personal during the measurement campaign, it was established that this is probably a result of the use of the cruise control. The driver with less experience did not use this possibility and consequently the driver behavior 2 was unstable.

The final consequence of the different way of operating the vehicle reflects on the distance specific mass emissions within the measurement steps (fig 26 and 27):

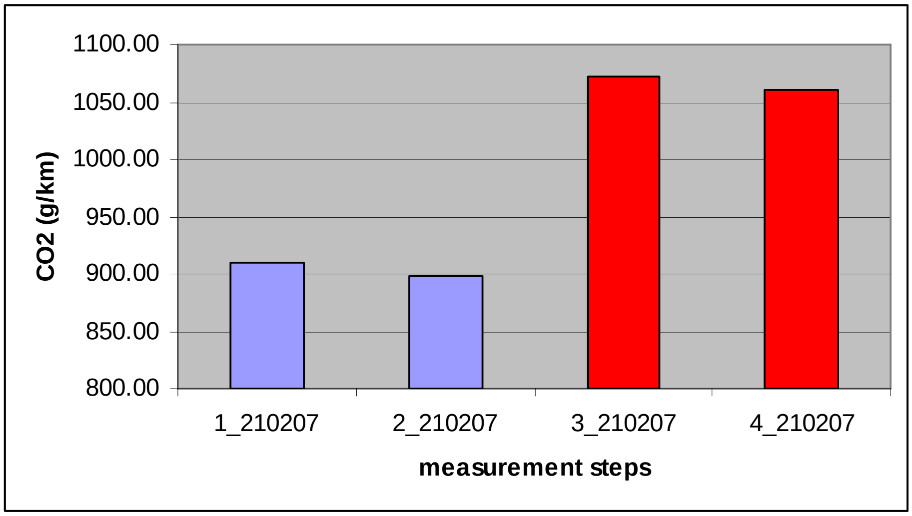

Figure 26 CO2 emissions per km for driver behavior 1 (blue) and driver behavior 2 (red)

The last two bars indicates the average emissions per kilometer for driver behavior 2. Compare to the driver behavior 1 the CO2 emissions are up to 18% higer.

The difference can be seen also at NOx emissions:

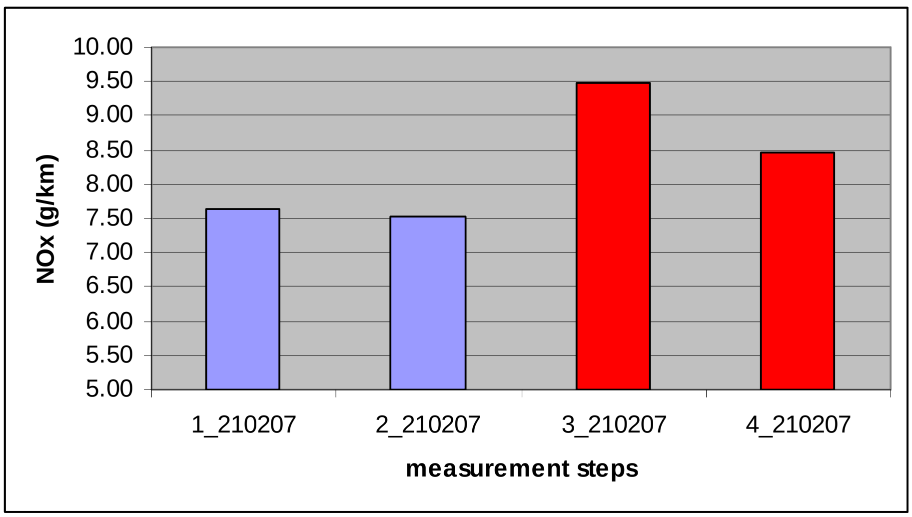

Figure 27 NOx emissions per km for driver behavior 1 (blue) and driver behavior 2 (red)

The NOx emissions are more sensitive for non fluent operating of the vehicle (throttle pressing). Within the third measurement step the consequence of driver behavior 2 was 24% more emissions compare to the driver behavior 1 and in the fourth step 13% more emissions. Obviously after previous ride (step) the driver behavior 2 was improved (the non expert drivers got experience how to operate the engine on more fluent and efficient way).

5.2.2. Influence of the acceleration of the vehicle

Observations of the acceleration of the vehicle from 40 km/h to reach the optimal operational speed (90 km/h) indicates that the non-expert driver needed more than twice the time and distance as compared with the expert driver. From the following Figures (figs 28 and 29) can be noticed also the oscillation of the speed when the gears were changed.

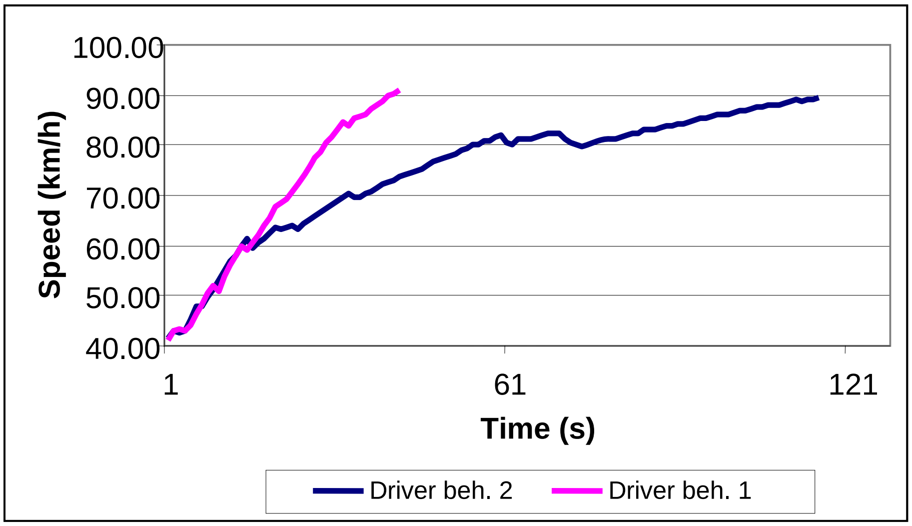

Figure 28 Acceleration from 40 to 90 km/h for driver behavior 1 (blue) and driver behavior 2 (red)

The non fluent operation of the gearbox reflects also on the engine speed:

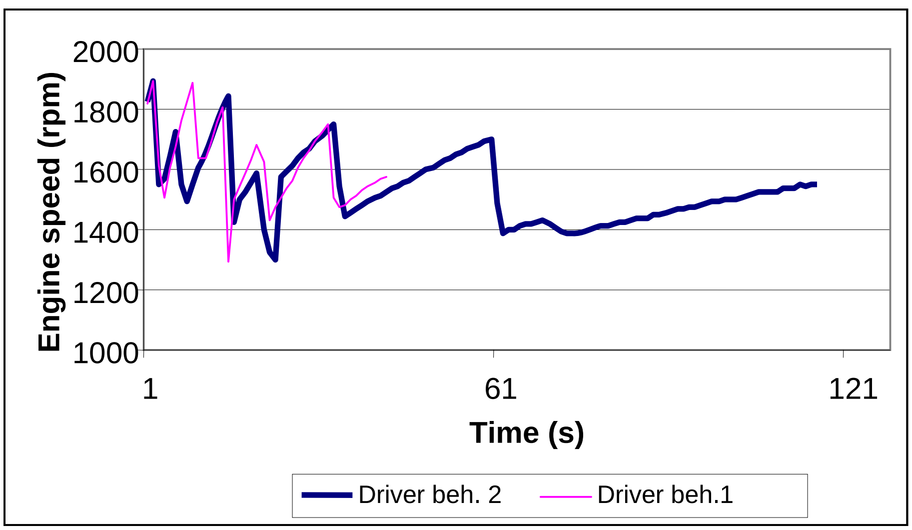

Figure 29 Engine speed during the acceleration from 40 to 90 km/h for driver behavior 1 (blue) and driver behavior 2 (red)

In the driver behavior 1 was the engine speed at optimal level and changing the gears rapidly compare to the driver behavior 2. For the acceleration from 40 to 90 km/h the consequence of the driver behavior 2 was 3,2 times more CO_2 and 2,8 times more NOx emissions as compared to the driver behavior 1.

It is well known the importance of the way a vehicle is operated but from the last set of figures it is obvious how high the emissions can be if the vehicle is operated in a non-optimal way.

5.3. Influence of the characteristics of the infrastructure

It is very difficult in practice to find the optimal type of road infrastructure. Due to geographical conditions the roads can not be only flat and straight and due to the different categories of roads the operation of the vehicle can be more or less optimal (fluent). The regimes of the traffic change from one type of road to other type.

5.3.1. Influence of the optimal and no optimal sections of roads

The main part of the measurements was performed in the motorway cycles, where flat sections are more frequent than up and downhill section. The last ones are not so distinct because of the motorway construction regulations (the maximum allowed slope change of motorways is 3%).

As mentioned before the heavy duty vehicles in the regular traffic are mostly half loaded. In respect to this the appropriate data were recorded on the journey from Barcelona to Ispra when the occupancy of the truck was 49%. Then, certain sections of the journey having the following characteristics were selected:

- The speed had to be on the maximum and optimal level (90 km/h)
- The selected road section has to have a constant slope

The data are presented as distance-specific emissions (g/km) and with respect to the percentage of the road slope.

On the flat section the emissions of CO_2 were in agreement with the average level of the measurement campaign which was 951 g of CO_2 per km. The emissions on flat sections oscillated from 750 to 800 g of CO_2 per km. In the case of a 2% of road raising the emissions increased up to 1600 g per km. In the case of downhill sections the emissions decreased up to 200 g/km. The relation between up and down hill vehicle operating emissions is clear and nearly linear (figs 30 and 31).

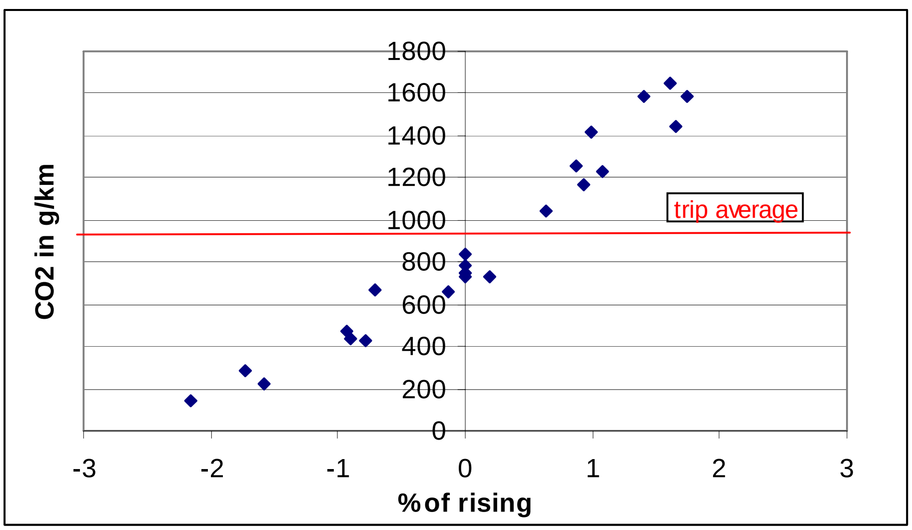

Figure 30 CO_2 emissions (g/km) as a function of the % of road rising

Almost the exact similar trend can be seen from the following comparison which shows the emissions of NOx for the same situations. The only difference is that the data are somehow more dispersed (because of the already mentioned NOx emissions sensibility with the way the accelerator is used).

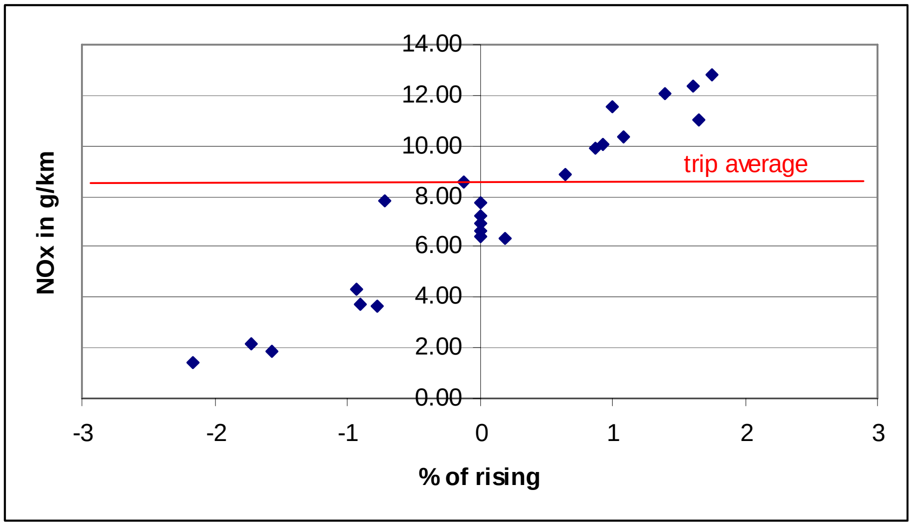

Figure 31 NOx emissions (g/km) as a function of the % of road rising

As a conclusion it can be said that flat sections of motorways contribute up to 30% less emissions of CO2 and up to 20% of NOx as compared to the average emissions.

5.3.2. Influence of the urban, suburban and rural cycles of vehicle operation

Non fluent operation of the vehicle is mostly present on the urban roads (in the driving urban cycles). The traffic regimes differ from stop and go regime in the urban areas to the fluent optimal operation regime at constant and optimal speed on the motorways. Between these two cycles a suburban cycle can be defined with lower and unstable speed regime with accelerations and breakings. Mainly these regimes are a logical consequence of the infrastructure characteristic:

- In urban areas (fig 32) traffic is mainly managed with traffic signs (traffic lights, stop signs, etc…), the speed rarely exceeds 50 km/h

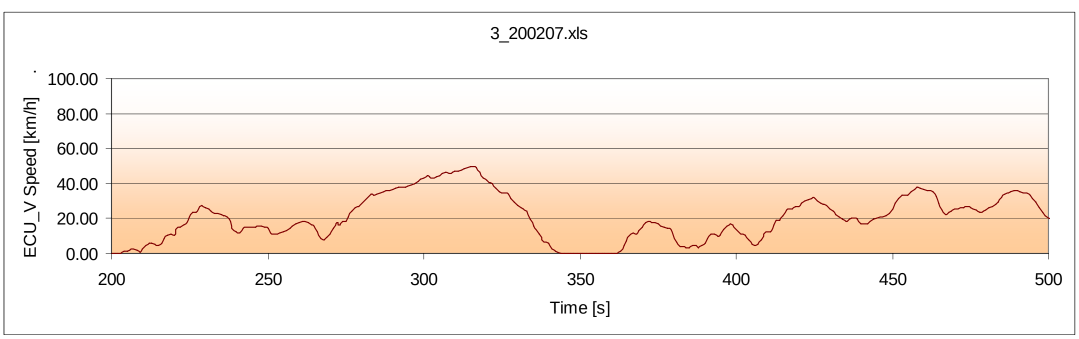

Figure 32 The oscillation of the vehicle speed in a 5 min urban operation cycle (step 3 on 20.2.2007 – journey from Barcelona to Ispra)

- In suburban areas (fig 33) traffic signs are not so common. The infrastructure is mainly designed according to suburban type of settlements (curves, roundabouts, narrow roads…) and the speed oscillates between 30 and 70 km/h

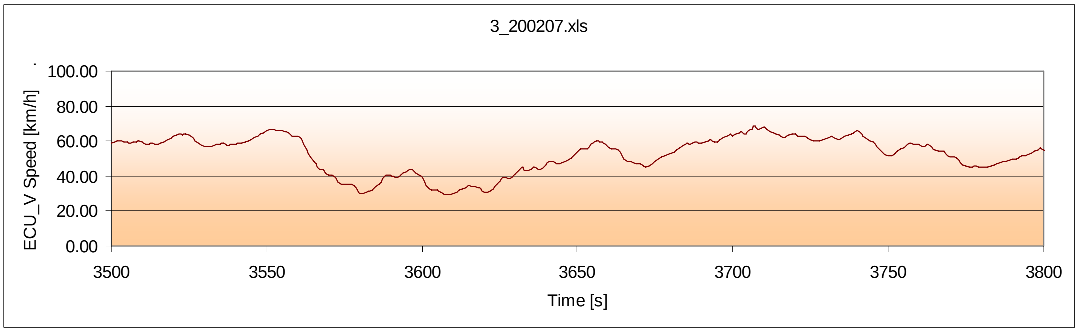

Figure 33 The oscillation of the vehicle speed in a 5 min suburban operation cycle (step 3 on 20.2.2007 – journey from Barcelona to Ispra)

- On the motorway (fig 34) the "traffic designed constrains" are practically not present and the vehicle can be practically operated on the optimal way, the speed is mainly constant at around 90 km/h

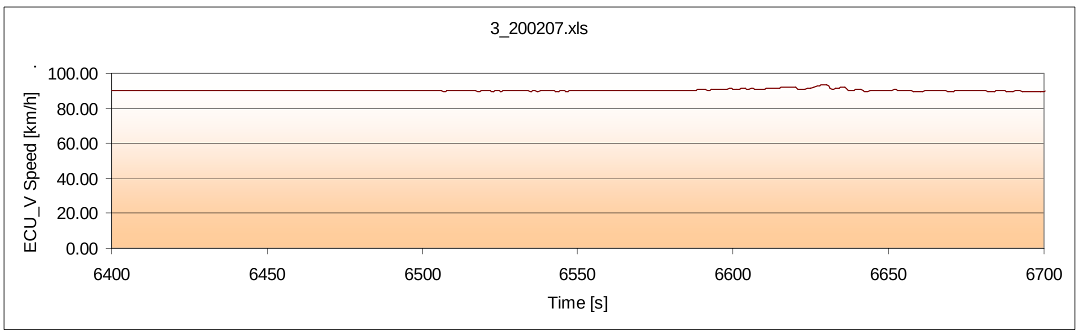

Figure 34 The oscillation of the vehicle speed in a 5 min motorway operation cycle (step 3 on 20.2.2007 – journey from Barcelona to Ispra)

Due to the above described traffic regimes the vehicle travelled in the same time period different distances. In the suburban cycle the vehicle travelled 2.6 times more distance than in the urban cycle. In the motorway cycle it travelled 4.5 times more than in the urban cycle and 1.7 times more than in suburban cycle.

As a final consequence the different cycles (regimes) of vehicle operation have its influence on the emissions. The following figures (35 and 36) of emissions are given for the 5 minutes sections mentioned above:

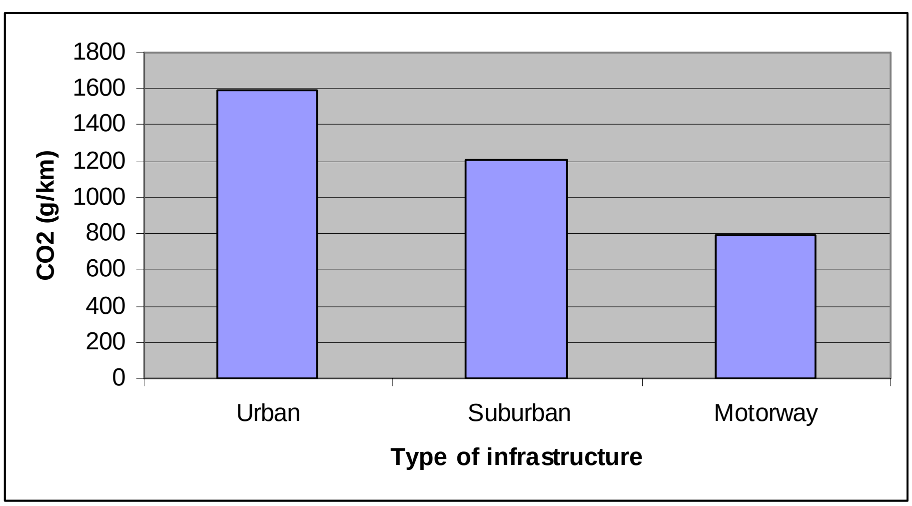

Figure 35 CO2 emissions on different types of roads (cycles of vehicle operation)

On the urban roads the CO_2 emissions are twice as high as on motorways and one quarter higher than on suburban roads. The discrepancy is more significant in the case of NO_x emissions, which are on urban roads nearly three times higher than on motorways.

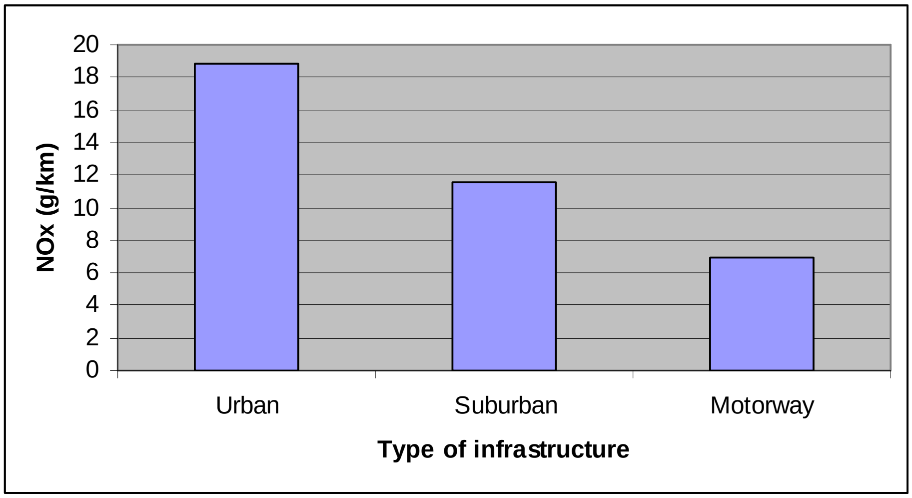

Figure 36 NOx emissions on different types of roads (cycles of vehicle operation)

5.3.3. Influence of the road conditions

The road conditions also influence the level of emissions. The influence of road surface does not seem to be very significant (rough or smooth road surface). During the measurement campaign such characteristics of infrastructure were not the object of the protocol. Also the measurement was not performed in the winter conditions with snow on the road. Consequently such influence of mentioned characteristics can not be evaluated in this report.

5.4. Influence of the transport flow density

Free flow traffic conditions are not very frequent in real traffic and are mainly present only on the highways at optimal speed. Due to constrains on the urban and suburban roads (signs, roundabouts, traffic lights, curves…) traffic flows are usually non fluent. It influences also the density of traffic which is higher in such areas. These circumstances were not detected in the protocol and the traffic density can not be derived more precisely from the recorded data. Fortunately the crew took notes manually of events such as traffic jams. These events can be then compared to the optimal free flow traffic conditions.

Until now the results of the analysis shows that the average emissions of the half loaded test vehicle in the optimal conditions (optimal speed, flat section of the motorway) are the following:

- 793,1 g of CO_2 per km and
- 6,9 g of NO_x per km

On its way back from Barcelona the vehicle was only once involved in a 5 min traffic congestion on the motorway A8 near Nice. The speed oscillated from 0 to 28 km/h and the vehicle drove 2 km in the mentioned time. The described situation was not a typical traffic jam. According to a transport terminology the fluency of the road traffic is segregated in four levels:

- Fluent traffic at constant speed
- Traffic at non constant speed (non fluent traffic)

- Stop and go traffic
- Discontinued traffic (vehicles stop for longer period – few minutes)

The mentioned situation near Nice corresponds more to the stop and go traffic situation. So the situation can be treated as typical non fluent traffic situation. The examination of the collected data shows that the vehicle produced on the mentioned congestion spot:

- 3088,6 g of CO2 per km and
- 28,3 g of NOx per km

This is four time more emissions if compared to the fluent traffic conditions. It is obviously that was the traffic congested already before the described event. The examination of the data indicates that the traffic became congested already 5 km before the critical event (stop and go regime). The speed of the vehicle oscillated between 45-76 km/h and consequently the emissions were following:

- 1010,4 g of CO2 per km and
- 8,21 g of NOx per km

The final comparison of the examination is the following (fig 37 and 38):

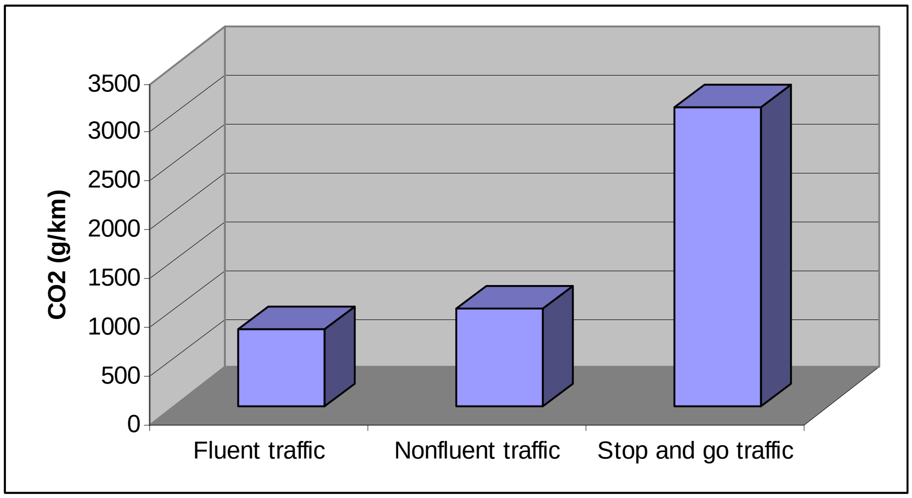

Figure 37 CO2 emissions compare to the level of traffic congestions (g/km)

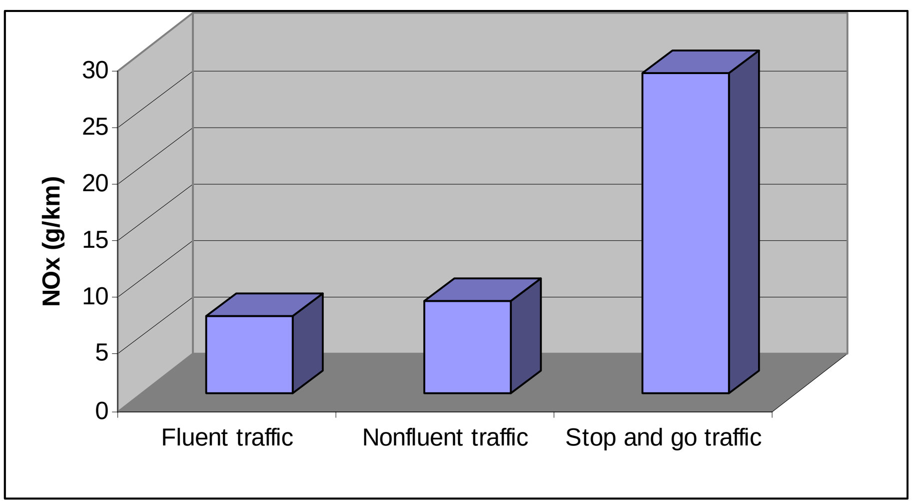

Figure 38 NOx emissions compare to the level of traffic congestions(g/km)

The results clearly show that the congestions have significant influence on the emissions. The emissions grow exponentially with the traffic density.

5.5. Influence of the extreme situations

In the real world road traffic appear the situations where the vehicle must stop either due to the road operational reasons such as toll payment or due to the administrative reasons such as border crossing or weight control.

These situations were examined on the section from Maribor to the border cross Fernetti because of the more familiar described extreme situations. There was only one administrative control at the time at Fernetti border pass (police control according the Schengen rules abolished on 1.1.2008). Comparatively toll stations at Venice and Trieste were examined too. It was necessary also to compare the mentioned extreme situations to the regular traffic conditions such urban, suburban and motorway cycle. The following traffic conditions at the mentioned spots were present:

- Toll station at Venice (I): The test vehicle only entered on the flat motorway section and stopped only once time for few seconds in order to get the entering ticket.
- Toll station at Trieste – Lisert (I): the situation was the same, the toll pay-line was empty, so the crews spent only a few seconds to pay the toll.
- Border crossing Italia/Slovenia at Fernetti: The vehicle spent more than 7 minutes because of the police control and it had to move and stop several times for intervals between 10 to 120 seconds. The row of the waiting vehicles was under the average level. The test vehicle was the eight in the row.
- Toll station Dane (SLO): The vehicle stopped for few seconds in order to get an entering ticket, the motorway inclined slowly at this point.
- Toll station Brezovica - Ljubljana (SLO): The vehicle was waiting for the payment one minute and it moved two times.
- Toll station Kompolje (SLO): The situation was similar to the previous one except that the motorway inclined at this point to.
- Toll station Vransko (SLO): The pass trough this station was fluent.
- Toll station Tepanje (SLO): The pass of this station was les fluent compare to the previous one (maybe was a human factor involved – counting of coins by the driver).
- Motorway cycle driving (SLO): The vehicle was running at the optimal speed and at the optimal infrastructure conditions (flat section of road).
- Suburban cycle of driving (SLO): The vehicle was entering in Maribor- The speed oscillated from 55 – 80 km/h (flat section of road).
- Urban cycle of driving (SLO): The vehicle entered in Maribor- The speed oscillated from 0 – 55 km/h. In the flat section of road the vehicle stopped few times because of traffic lights.

All described situations are depicted on figures 39 and 40:

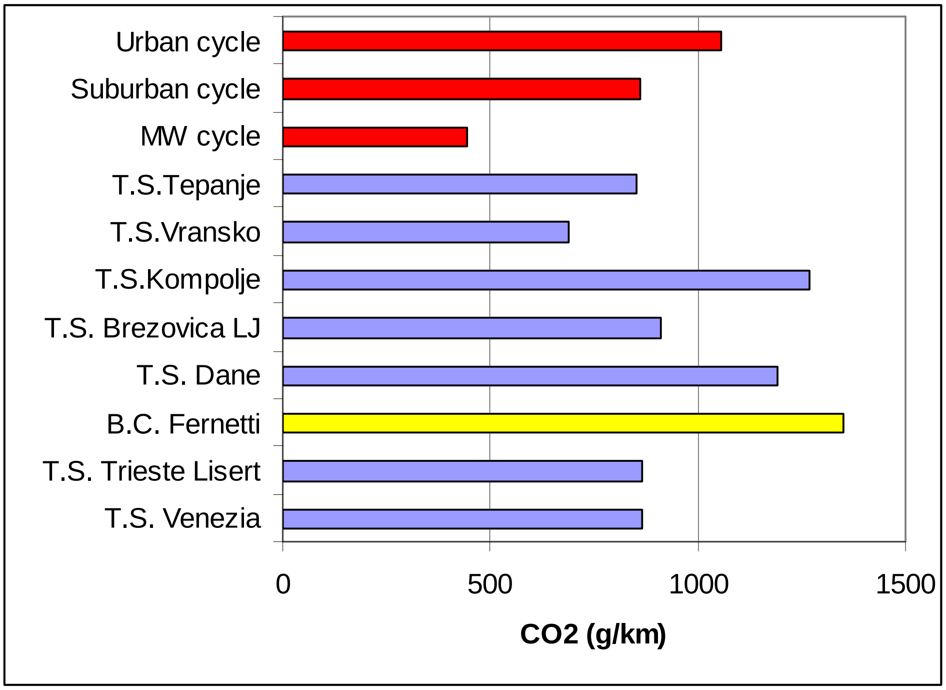

Figure 39 CO2 emissions at toll stations and border crossing compare to the different cycles of driving

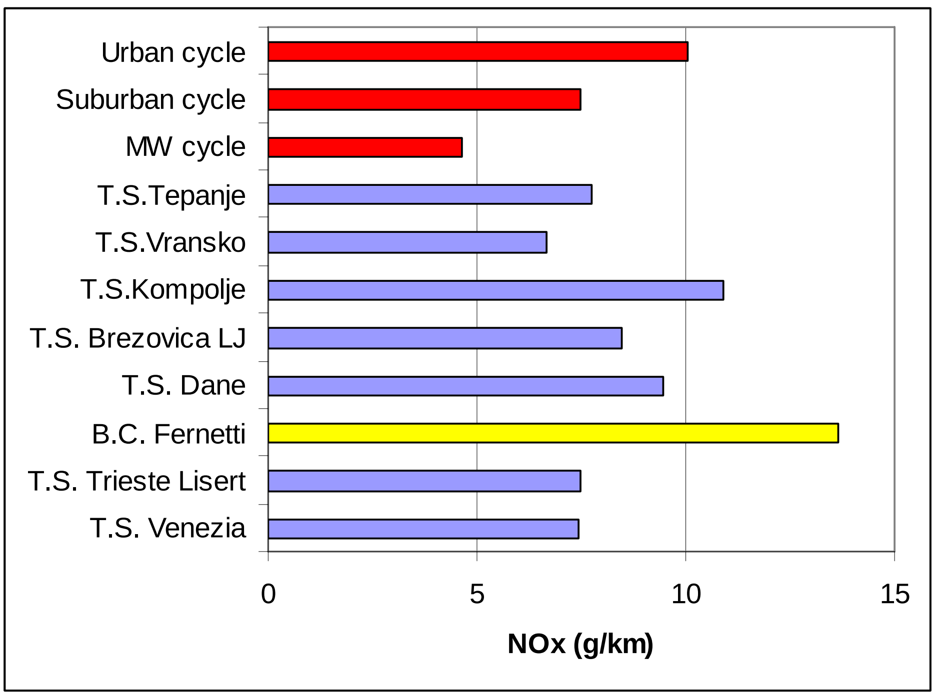

Figure 40 NOx emissions at toll stations and border crossing compare to the different cycles of driving

The results show that any interruption of the transportation process contributes to higher emissions; at least one third more as compared to the optimal conditions. If the waiting time is longer (border crossing Fernetti) and if the stop spots are placed on the inclining section of the roads (Toll stations Dane and Kompolje) the emission can be higher than in urban road sections. It must be emphasized too that the measurement on mentioned critical spots wasn't performed during the rush hours. In the high season the rows of heavy duty vehicles are much longer and the waiting time can be much longer (up to several hours).

6. INFLUENCE OF THE LOGISTIC FACTORS

Main logistical factors which can influence on the emission are linked to:

- the occupancy rate of vehicle
- manoeuvrings of the vehicle on the logistical areas such as gas stations, yards, up and down loading areas…
- other operations of the vehicle such as warming up of the engine, heating of the cabin in the case of the rest of the driver…

6.1. The influence of the occupancy rate

The influence of the occupancy rate on the emission was described under the chapter on “Influence of the vehicle parameters”. The occupancy rate is the most important characteristic and parameter in respect to the transport economical and transport sustainability points of view. In the economical and in the sustainable sense means higher occupancy rate better utilization of transport mean. The only difference is in the consequences. The economical consequences are lower costs per unit of carried goods and the sustainable consequences are lower emissions per unit of goods.

6.2. The influence of the manoeuvrings

The detailed manoeuvrings of the vehicle were not recorded. From the manual records is evident for what purpose vehicle stopped (refilling, instrument calibrations…). Other detailed manoeuvres (approaching to the ramp, turning up of the vehicle…) were not recorded.

From the collected data set, those data which can be attributed to the vehicle manoeuvring can be extrapolated and the following parameters calculated:

- emissions at lower – manoeuvring speeds (up to 40 km/h)
- emissions at idle engine regime

Because the vehicle in the manoeuvring regime is operated in totally different way as in traffic flow on the road the emission values expressed in g/km can not be applied. At manoeuvring operations the vehicle mainly is standing or is moving at very low speeds. The overall driven distances are small compare to the time the vehicle is running. In a road operation the true conditions are just opposite. Because of this time dimension influence only the emission values in terms of g/s can be applied in this part of analysis.

The examination of the recalculated data indicates that the emissions in g/s term are growing constantly with the growing of the speed of the vehicle up to 50 km/h. After this highest point the emissions started to fall up to the speed of 90 km/h. A small oscillation can be noticed however the trend is quite strong.

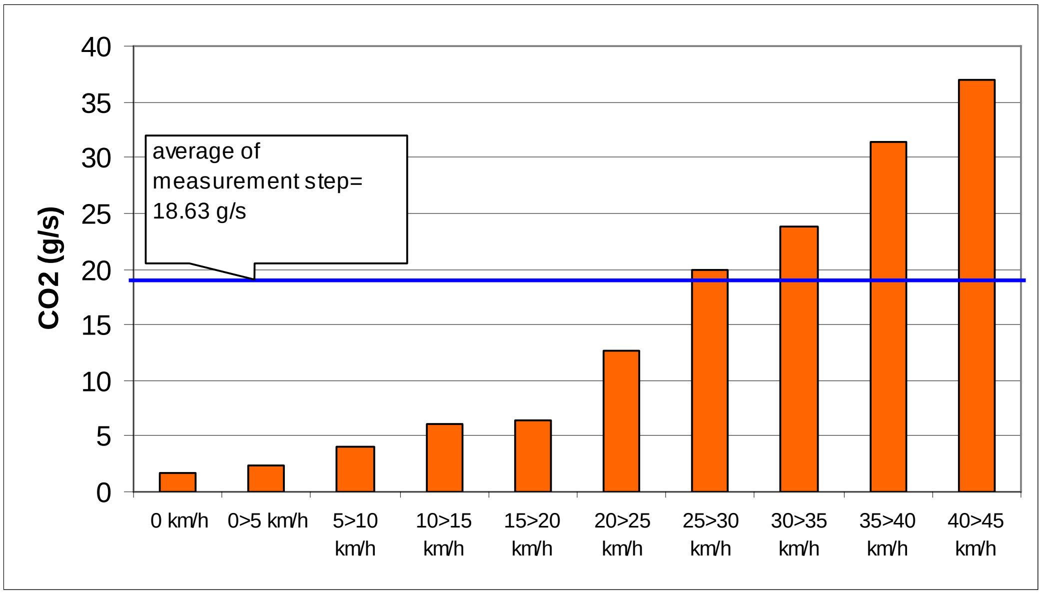

Figure 41 Average CO2 emissions in g/s within the differed speed classes as compare to the average level in a measurement step

The oscillation is a little bit more significant at NOx emission but the trend is still notable:

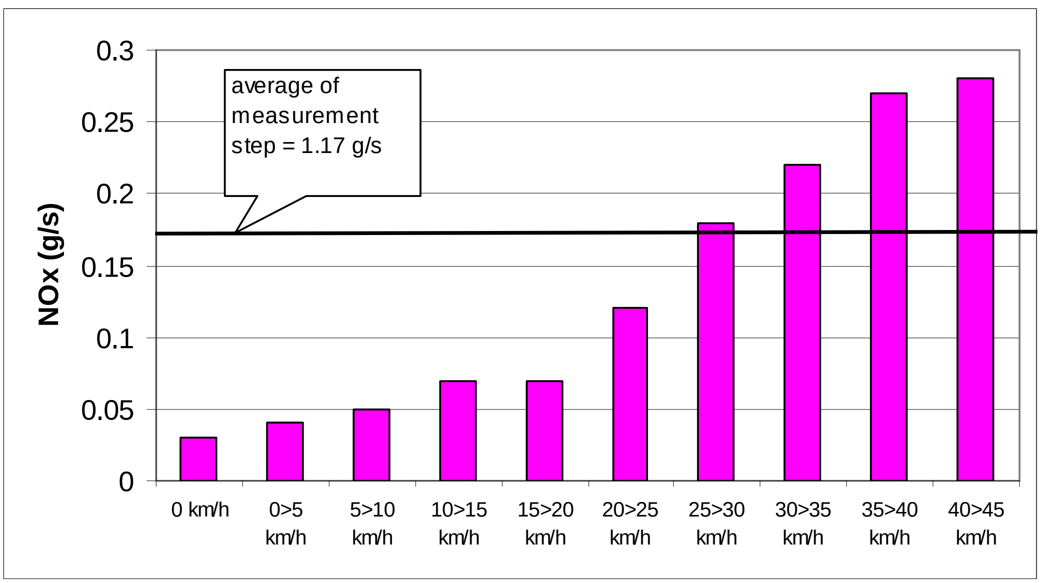

Figure 42 Average NOx emissions in g/s within the differed speed classes as compare to the average level in a measurement step

The speed of the manoeuvring vehicle is up to 5 km/h. Because of the goods handling regulations the speed in the loading and offloading areas is usually limited to 10 k/h. A closer look on the average emissions up to the speed of 5 km/h shows that the critical point is at speed between 0 and 2 km/h when the engine needs more power to move the vehicle from the stop position.

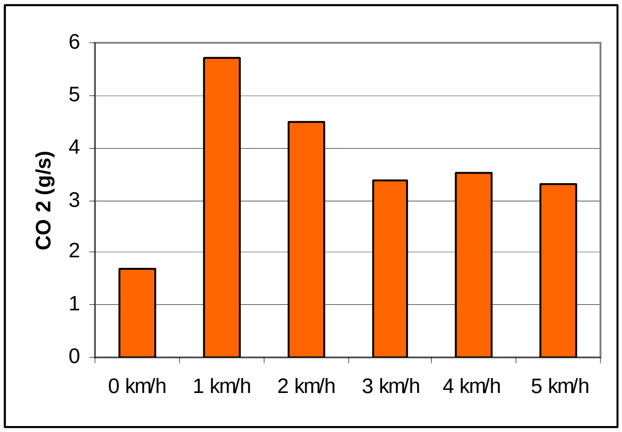

Figure 43 Average CO2 emissions in g/s within at lower speeds (speed of maneuvering)

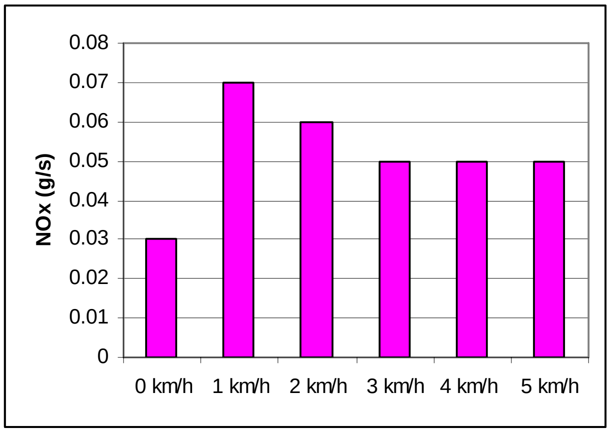

Figure 44 Average NOx emissions in g/s within at lower speeds (speed of maneuvering)

As noticed at the beginning of this chapter these data are not comparable on the basis of g/km. If the emissions of CO2 would be expressed in g/km term at a speed of 1 km/h then would be up to 15 times higher compare to the emissions at the average speed and in the case of NOx emission this value would be up to 30 times higher. In the real world transport cycle no vehicle is travelling at speed of 1 km/h therefore the emissions need to be differentiated between the manoeuvring period and the road transport operations. It would be interesting to see the share of the manoeuvring emissions in total but for this evaluation a more exact records of manoeuvring are missing. This share can be only guessed from the collected data and seems to be negligible (it represents less than 1% of the total emissions).

6.3. Other operations of the vehicle

When the vehicle engine is idle, it produces emissions which can be compared only on the time dimension basis (g/s). These emissions are quite constant in an idle engine situation, the only difference is between emissions of an already warmed engine and a cold engine. The exact difference between emissions of cold and warm idle engine is depicted in figure 45:

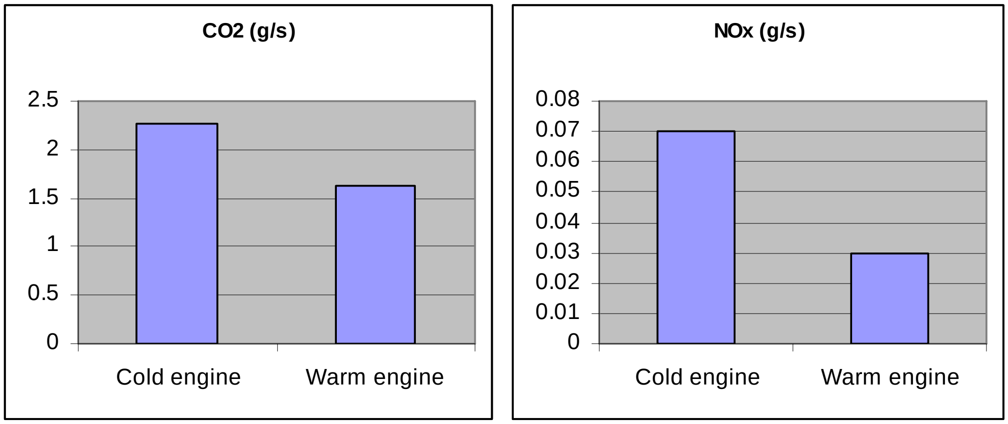

Figure 45 CO2 and NOx emissions at warm and cold engine

The discrepancy in the above situations is more significant in the case of NOx emissions.

Only situations where the vehicle engine was idle were recorded. Other specific circumstances like, cabin heating in the case of the driver rest, manoeuvring in the logistic area etc, were not recorded, hence these operations can not be evaluated.

7. CONCLUSIONS

The report is based only on the collected data during the measurement campaign and for one heavy duty vehicle. For more exact study it would be necessary to perform several measurement campaigns with different types and engine classes of vehicles. The performed campaign was treated as a preliminary one in order to study the possibility to perform such long distance measurements. The purpose was also to validate the usability of collected data and trough the analysis to detect what kind of additional data should be taken in future campaigns.

The crew proved that is possible to perform long distance measurements. The figures clearly show that the vehicles with their dedicated environmental technical characteristics in the real traffic conditions produce totally different emissions as compared to those in the laboratory. These emissions are mainly linked to the described factors and are reflected as a variable in time and distance and it can not be treated as a constant value in equivalent traffic situations.

7.1. The influence of the parameters

It is well known that the technical progress of vehicle engines was significant in the past and the emissions of comparable engines are much lower than 20 years ago. But the main question is still if was made adequate progress on:

- the traffic operation management of roads
- the road designing field
- the transport policy measures
- the transport logistic field
- etc…

The influence of technical, operational and logistical parameters is now mainly the consequence of the mentioned progress. This report clearly shows how high emissions can be at critical points:

- stops for administrative reasons (toll stations, controls…)

- congestions as a consequence of non improved traffic managements
- non synchronized suburban and urban traffic management
- non economic operations (low load occupancy)
- non educated operators of the vehicles
- etc…

In the short term the emissions at mentioned points can be decreased with low costs measures. It is just opposite at critical points which are linked to the infrastructure improvement and which are costly and long term measures.

7.2. The recommendations

The model for the data collection was designed primarily as a tool for the observation of the engine parameters and its influence on the emissions. Only a small amount of data can be designated as data which are directly linked to the traffic and infrastructure conditions (i.e. speed, geographical position, altitude…). Practically the majority of comparisons in this report were statistically derived from the collected ones (mainly with the observation method). According to this experience the model for data collection has to be upgraded with the following measurement parameters:

- the emissions per ton-kilometres in time
- indication of cycles of driving (urban, suburban, motorways…)
- indication of transport flow density
- indication of other interruptions of the transport operation (bottlenecks, rests…)
- indication of other important events (i.e. manoeuvring)

The first two can be easily recalculated from the data. Others can be taken manually and then introduced in the model or, can be taken with video device and stored in the computer memory with linkage to the PEMS data. The solution can be also on time and on spot indication of traffic situations in the computer memory. These solutions can enable more exact analysis and comments of the produced emissions in different traffic conditions.

In order to extrapolate the data to “vehicle population” along a transport corridor additional tests are needed. To specify the test measurement strategy also the Corridor fleet composition study should be carried out in order to develop the strategy of the possible future measurements campaigns.

One of the aims of the project was also to improve (to verify) the emission factors used in the different emission models. The findings of this analysis can be in the next step compare to the emissions factor of the similar vehicle in the different emission models.

European Commission

EUR 23659 EN – Joint Research Centre – Institute for Environment and Sustainability
Title:Technical, Operational and Logistical Parameters Influencing Emissions of Heavy Duty Vehicles
Author(s): M. Pregl, A. Perujo, P. Bonnel
Luxembourg: Office for Official Publications of the European Communities
2008 – 45 pp – 21,0 x 29,7 cm
EUR – Scientific and Technical Research series – ISSN 1018-5593
ISBN 978-92-79-11071-9
DOI 10.2788/52697

Abstract

The focus of this study is the analysis of collected data of real world emission measurements of a heavy duty vehicle using a Portable Emission Measurement System (PEMS) along a large portion of the extended Trans-European Transport CORRIDOR V. The aim of the analysis is to assess heavy duty vehicle emission in different real-world transport conditions and their correlations i.e. transport factors influencing emissions.

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

LB-NA-23659-EN-C

EUROPEAN COMMISSION

Publications Office
Publications.eu.int

ISBN 978-92-79-11071-9